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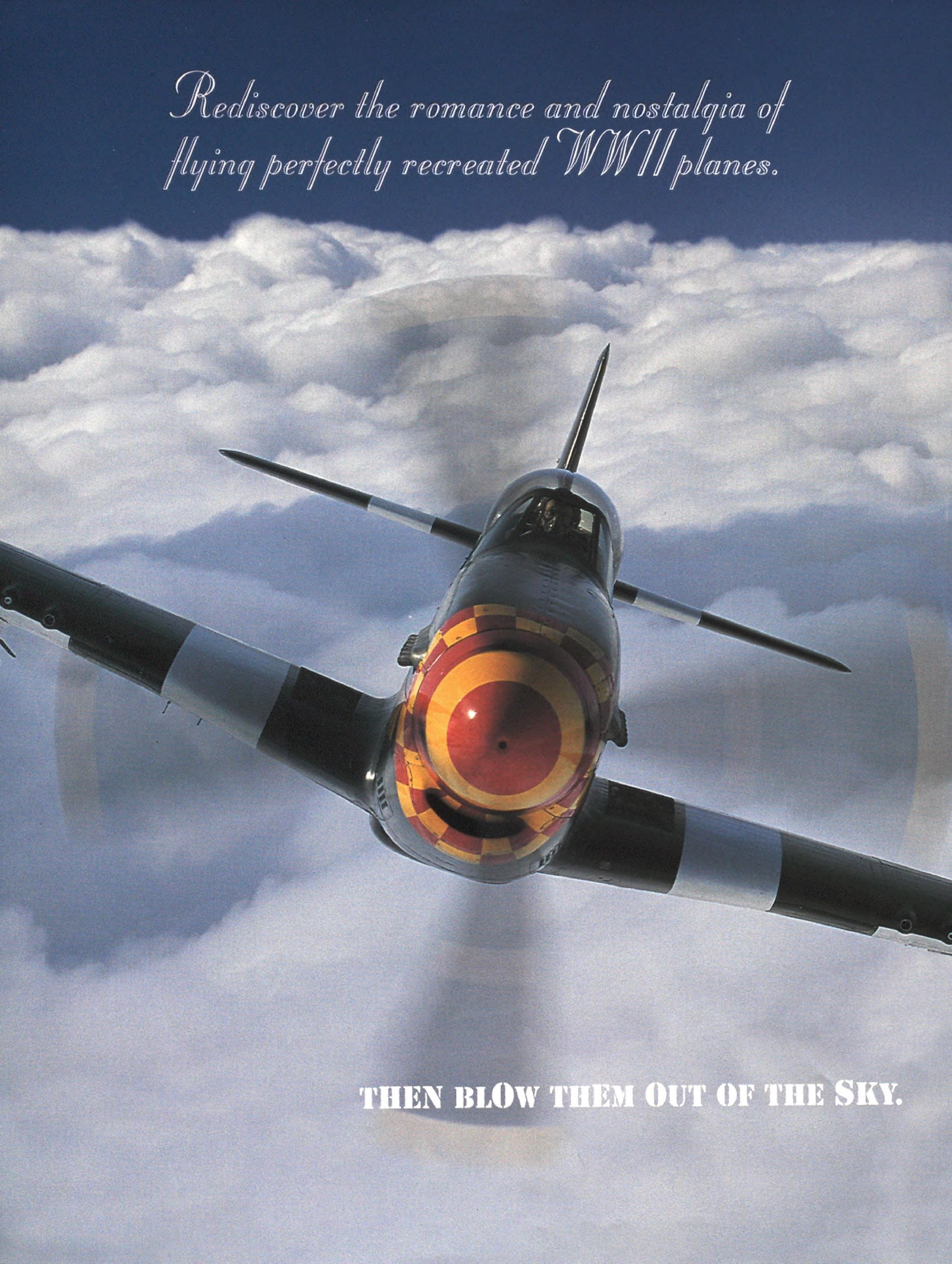
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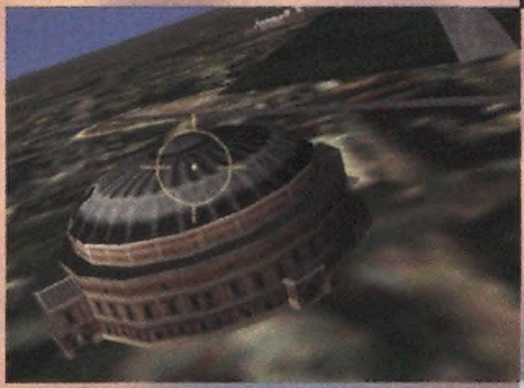

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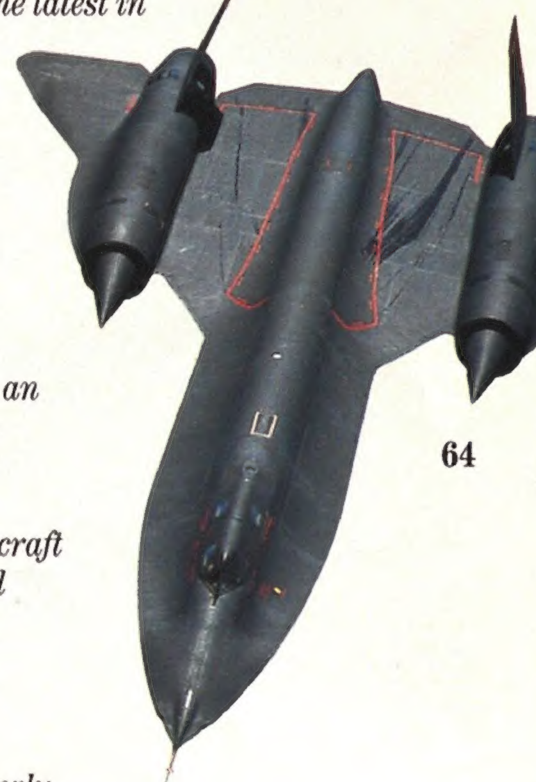
CONTENTS


22


46


54


64

Cover: Chad Slattery backed an A-10 into a corner and captured it with its teeth bared, poised to strike.

Departments

AIR & SPACE CONTEST
Page 8

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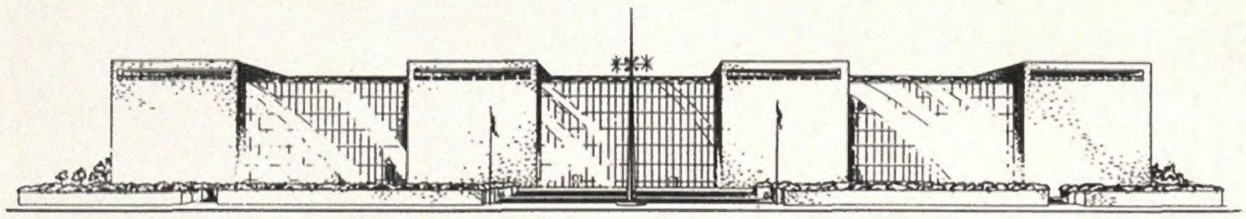
VIEWPORT



Restored Luster

Igor I. Sikorsky designed and built three VS-44A seaplanes for American Export Airlines. AEA named the seaplanes *Excalibur*, *Excambian*, and *Exeter*, and they were first flown in 1942. With a giant high wing and four Pratt & Whitney 1,200-horsepower Twin Wasp engines each, these great seaplanes were the first aircraft to fly mail and passengers across the Atlantic nonstop.

Excalibur was lost in a takeoff accident in October 1942. *Excambian* and *Exeter* were placed in wartime contract service for the Navy and flew people, cargo, and mail across the Atlantic until October 1945, when the civil DC-4, a fast land-based airliner, eclipsed the slower flying boat. The two surviving VS-44As were sold and flown in charter service in South America. *Exeter* crashed in 1947 during a night landing on the Rio de la Plata while carrying a load of arms for Paraguayan rebels, and *Excambian* was later stored near Lima, Peru.

Wilton R. Probert, president of Avalon Air Transport, which flew Grumman Goose amphibians between Long Beach, California, and Catalina Island, bought the *Excambian* in 1957 and added it to his fleet. Known as "Mother Goose," *Excambian* plied the short 21-mile distance day in and day out until 1967, when former naval aviator Charles Blair and his wife, actress Maureen O'Hara, bought the seaplane for their own company, Antilles Air Boats, operating it inter-island from a base at St. Thomas in the Virgin Islands. Blair may have had his eye on the airplane for personal reasons: As an AEA pilot, he had made his first flight in a VS-44A in 1942.

The Blairs' sentimental attachment ultimately resulted in their donation of *Excambian* to the National Museum of Naval Aviation in Pensacola, Florida, in 1976. Two years later, Charles Blair was killed while landing a Grumman Goose. In 1983, Maureen O'Hara, with the help of National Air and Space Museum curator Robert Mikesh, arranged for *Excambian* to go on permanent loan to the Bradley Air Museum (since renamed the New England Air Museum) in Windsor Locks, Connecticut. The once-proud *Excambian*, now tattered and forlorn, was transported by ocean-going barge from Florida to the Sikorsky Memorial Airport in Connecticut and then moved to a hangar not 300 yards from where it had been built 36 years before.

On November 4, 1987, Eugene Buckley, chief executive officer of Sikorsky Aircraft, pledged his company's support and began what would become an 11-year restoration led by retired Sikorsky employee Harry Hleva. During this time, a team of 113 retirees worked as volunteers; of this group, 28 would pass away before the project could be completed. A number had helped to build *Excambian*, and all labored with dedication. Joe LoSardo worked on the bulkheads and formed the new windshield in his kitchen oven. Vic Politi restored the radio operator's station, while Greg Fuimara and Dom Palumbo reskinned and put finishing touches on the hull. The flight deck and cabin interiors were completely restored, and the seaplane was painted its original silver.

Finally, *Excambian* was complete and was moved by road to the New England Air Museum. Last November 19, former owners, pilots, stewardesses, and other crew members came from far and wide to join the restoration crew and company employees for the recommissioning. It was a true family affair, with 800 attending. At the dedication ceremony, I was honored to join Larry Churchill, president of the Connecticut Aeronautical Historical Association, Eugene Buckley, and Maureen O'Hara on the dais in front of the gleaming *Excambian*. While the airplane is complete and ready to fly, she will take wing only in the imagination of visitors who come to see this great and historic seaplane. I'm not sure I do justice to this restoration of a classic flying boat in these few words, but *Excambian* is a tribute to all who have been associated with her.

—Don Engen is the director of the National Air and Space Museum.

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LETTERS

Déjà View

The picture of the Bristol Beaufighter cockpit (Sightings, Dec. 1998/Jan. 1999) brought back memories. All the British planes I flew—de Havilland Tiger Moth, Avro Anson, Airspeed Oxford, Bristol Blenheims (Mk1 and Mk4)—had exactly the same panel. No matter what you flew, you knew where to find the critical flight instruments. Transition was much easier that way! In American planes, on the other hand, the first thing you have to do is look for those critical instruments.

A wag once said that the British designed an airplane around the pilot, while the Americans designed an airplane around the power plant and, if there was any room left, added a pilot.

—George Sutton
Poland, Ohio

The Long Reach of Canada's Influence

The first two modules of the international space station have been joined ("Birth of a Station," Dec. 1998/Jan. 1999). Now it is time for the editors of *Air & Space* to begin referring to the manipulator arm by the term informed Canadians use: the Canadarm. You recognize other countries with projects in space, but you fail to acknowledge the Canadian technology that has played an indispensable role in many shuttle projects to date—e.g., the Hubble repair mission—and will be even more indispensable as the space station proceeds.

—Charles Grierson
Richmond, British Columbia

Mach Legends

I believe that the first pilot to exceed Mach 1 was neither George Welch nor Chuck Yeager ("Mach Match," Dec. 1998/Jan. 1999). During and after World War II, there were reports of pilots who died in crashes after making high-speed dives from which they were unable to recover. They probably had encountered the then-unknown phenomenon of Mach Tuck. I have little doubt that they experienced speeds greater than Mach 1 but didn't live to tell about it.

—Martin A. Snyder
Concord, California

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Before entering, please read the detailed rules, which are posted on page 86.

The caption in "Mach Match" that reads "All the American aces of that conflict [the Korean War] were F-86 pilots" overlooks Guy Bordelon, night fighter, F4U driver, and the only Navy ace of the conflict.

—Nick Coleman
Martinsville, Virginia

My memories of the Sabre and supersonic flight go back to 1952, when my father returned from the Korean War and was assigned to serve as maintenance officer to the 516th Air Defense Group at McGhee-Tyson airport near Alcoa, Tennessee. F-86s were based there to defend the nuclear facility at Oak Ridge, the Tennessee Valley Authority dams, and the Alcoa aluminum plant.

When my parents took us to family nights at the officers' club, I became friends with the F-86 pilots. At one party, some of the pilots took my brother and me out to the flightline. Then they slid the canopies of their Sabres back and directed us to get in the pilots' seats. There we were, sitting in the greatest machines in the world.

I could hardly keep track of all those dials and switches, but I do remember the Mach meter and the pilots' stories, including their exploits in the mysterious regions where "funny" things happened, like the airspeed indicator hanging up and "all of a sudden the plane got real smooth and quiet." One story recounted a Sabre zooming over the "commies" and going "BOOM," scaring them out of their trenches so the A-26s could attack their positions. Then one of the pilots would say: "We better not talk about this."

I had heard higher ranking Air Force officers declare that the F-86 was not even specified to be able to go Mach 1 and that there was thus nothing to talk about. The younger pilots, veterans of Sabre exploits in Korea, just grinned.

—Leslie F. Rice III
Garden Grove, California

A Crude Solution

I would like to clarify the assertion that the fuel developed for the U-2 was JP-7 ("Inventing the Spyplane: That New Black Magic," Dec. 1998/Jan. 1999). In early 1956 I joined the Esso Research and Engineering Co., which had been asked to develop a fuel for the U-2's modified J-57 engine. My first assignment was to select a crude from which a kerosene fraction with a low freezing point could be cut. The Air Force issued a special procurement for 100,000 gallons of the product, which was dubbed JP-X.

BYRON HARRIS

to have ready for a full test flight by the fall of 2000. It will be comparable in payload capacity to the Russian Proton rocket, which recently put Zarya, the first element of the international space station, into orbit, and will be able to place five-ton satellites into geostationary transfer orbits.

Unlike the Proton, the French Ariane launcher, and U.S. rockets now carrying commercial communications satellites into space, the BA-2 does not have high-speed pumps, ultra-pressurized tanks, and cryogenic fuel at the heart of its propulsion system. "We have just a fraction of the number of parts," Beal says. "It's just a lot simpler."

Although Beal admits to having a fascination with space, it's the economics of the launch business that attracted him to building rockets. He learned that three to four dozen commercial satellites are scheduled for liftoff each year for the next decade. Beal figured he could find a way to put them into orbit more cheaply than the handful of established aerospace firms that have the market cornered. The holy grail for launch cost—a goal not yet achieved—is $6,000 a pound. Beal predicts the BA-2 will be below that.

The BA-2 will use hydrogen peroxide and kerosene fuel. A high-pressure stream of hydrogen peroxide, broken down into steam and oxygen, will be the oxidizer. The oxygen will combine with the kerosene to produce thrust. The same propellants the Germans used in their V-2 rockets during the Second World War, these fuels can be stored at room temperature rather than the sub-zero temperatures required by the liquid hydrogen and oxygen used by many current launchers. While they don't deliver quite the kick of super-cold fuels, they're inherently more stable, don't require high-pressure pumps, and allow for weight saving in the plumbing and engine that more than compensates for the fuel's lower specific impulse. The BA-2 will use pressurized helium gas to force the propellants through the tanks.

The tanks—and just about everything else for the BA-2—will be manufactured at Beal's new facility in Frisco, Texas, north of Dallas. There, the fuel tanks, which are the core of each booster, will be wound out of lightweight carbon fiber thread. Each stage of the rocket will have just one engine. The first will develop three million pounds of thrust, the second, about a million and a half, and the third, about 33,000. When assembled, the three stages will stand 223 feet tall. After fabrication, they'll be shipped to the company's launch facility on the island of Sombrero in the British West Indies for mating.

Since Sombrero is only a mile long and three-eighths of a mile wide, the entire island will be devoted to Beal activities (the company has an agreement to lease it for 49 years). The island lies in a good position to launch into a number of trajectories, but Beal's intentions have drawn the anger of environmentalists, who say Sombrero is a vital nesting and breeding habitat for seabirds. The company counters with the argument that none of the species in question are endangered, and that the nests are regularly destroyed during hurricane season.

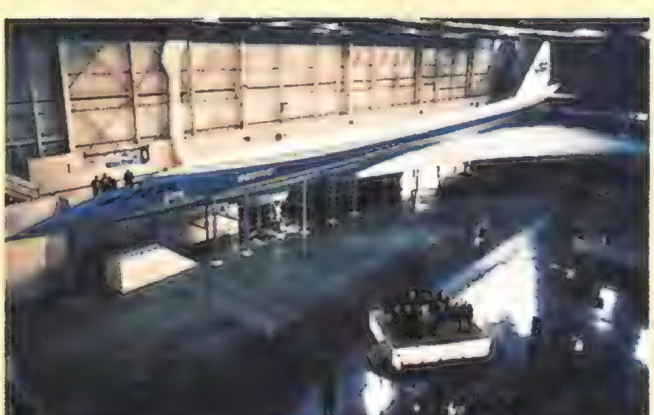
As he stood next to his six-foot-tall upper stage on test day, Andy Beal was a long way from orbit. His competition—Boeing, Lockheed Martin, Arianespace, and Russia's Krunichev—are all developing cheaper launch vehicles, based on proven technology. Beal's way, although simpler, has never been used in a rocket the size of the BA-2. "Whenever you make something simpler," he says, "it almost always leads to something better."

—Byron Harris

UPDATE

DANIEL A. PURSELL

HILLER AVIATION MUSEUM

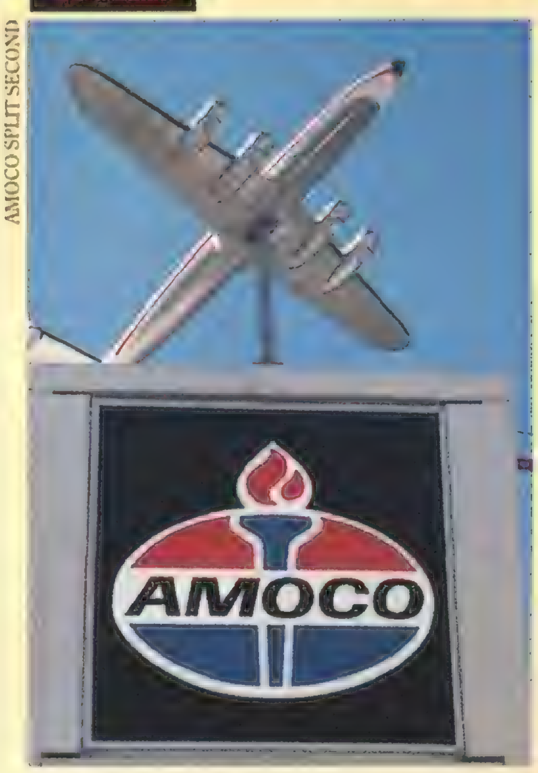


SST Revival

Boeing's supersonic transport prototype (left), a vagabond since the program's cancellation in 1971 (Soundings, "Holy SST!," Dec. 1990/Jan. 1991), has been rescued from the grounds of an old steel plant in Florida (above) and is undergoing restoration at the Hiller Aviation Museum in San Carlos, California. Museum president Stanley Hiller Jr., founder of helicopter manufacturer Hiller Aircraft, served on Boeing's board of directors for 22 years and enlisted the company's help in evaluating the condition of the mockup and transporting it cross-country. Boeing will also advise the museum on the restoration effort.

UPDATE

AMOCO SPLIT SECOND



Honey, I Shrunk the Connie

Now that the Lockheed Constellation that graced an Amoco Split Second station in Penndel, Pennsylvania ("Offbeat Landings," June/July 1991), is ensconced at the Dover Air Force Museum in Delaware, Amoco has replaced the landmark with a mini-model. The fiberglass replica, which has an eight-foot wingspan, was dedicated last October and will commemorate the Super G Constellation that was a local landmark for 30 years.

The Pelican Brief

DAVID CLARK

Northern Nebraska's prairie land is mostly rolling, grass-covered ranch- and farmland dotted with lakes, interrupted only by back roads and the occasional town. In other words, no distractions. And that was just the way David Lundquist wanted things early last May 13. He was completely concentrating on David Crowden, a mile or so to his left. The two men were covering a lot of Cornhusker country quickly—at 585 mph, actually—as they hustled their F-16Cs along a military corridor.

The training mission the two Iowa Air Guardsmen were on that morning called for low-level navigation followed by simulated ground attack runs. The pair was flat-hatting across the empty spaces at 800 feet. Lundquist was the wingman, so his head was mostly locked left, eyes riveted on Crowden. At one point he looked right momentarily and thought he noticed a flash of white.

Instantly Lundquist's world exploded. There was a roar and the pilot's helmet was torn from his head, the face mask ripping across his eyes. He couldn't comprehend what had occurred, but it was clearly catastrophic. He reached down and pulled hard on the ejection seat handle. Bareheaded, blinded, and confused, Lundquist was launched into a fearsome hurricane. Within seconds his Falcon was transformed into a black hole of smoking debris and his parachute was dragging him, unconscious and face down, across the ground.

The fighter was beyond salvage, but not its pilot. Although he fractured his left leg in two places, sprained both ankles, dislocated his left elbow and shoulder, broke his right shoulder blade, and traumatized his left eye, the 25-year Air Force veteran was out of the hospital in less than a month. By year-end, he was hoping to soon return to flying duties at American Airlines.

What happened up there? Sifting through the debris, Air Force investigators began pulling feathers out of the carnage. Bird remains were found in the engine and at least one had blown through Lundquist's canopy. The investigators concluded that the F-16 had clobbered five to eight American White Pelicans, birds that weigh about 15 pounds and are common in the Midwest.

Reflecting on the incident, one pilot with Lundquist's unit, the 185th Fighter Wing, said, "I've been hit by a sparrow and it sounded like a 30-mm round. A 15-pound bird would do as much damage as an artillery shell." That Lundquist survived "is a miracle," he said.

As a result of Lundquist's accident, the 185th called in William Seegar, a Ph.D. working for the Pentagon who has helped to develop a Bird Flight Forecast and Information System. By fitting wild birds with altitude-reporting transmitters, recording air temperatures at various altitudes, and following flocks to their nesting and foraging sites, Seegar and his colleagues came up with patterns of bird activity he says are as predictable as the weather.

The pilots with the 185th will soon be getting birdie briefings before launching because, as David Lundquist learned, a Fighting Falcon is no match for a pelican.

—*William Garvey*

More Bang, Big Bucks

On a cold, rainy Saturday afternoon last November in central Texas, history just might have been made. Four dozen hopeful souls stood ankle-deep in mud, gazing over a pasture to see if conventional rocket science could be proved wrong.

Their attention was riveted on a four-story concrete test stand on a former Navy rocket facility. Just after noon, a crackling roar rolled across the field as a billow of steam burst out from the cement wedge. Then the steam turned orange, and for 29 seconds, a cylinder of fire, perhaps a hundred feet long, stretched across the pasture.

Forty-five-year-old Andy Beal let out a whoop. He's a banker, not a rocket scientist, but he's sinking a quarter of a billion dollars of his own money into Beal Aerospace on the bet that his rockets will be able to put satellites into orbit more cheaply and efficiently than the launchers now on the market (see "Rockets for the Rest of Us," Feb./Mar. 1998).

On the test stand was the upper stage of the BA-2, a vehicle the company plans

Thermal stability was also the main requirement for JP-7, but that fuel was used for the U-2's successor, the SR-71.

—William G. Dukek
Maplewood, New Jersey

Editors' note: We regret the error, which was introduced during editing.

Not His Idea of "Strict"

In the last issue's Letters section, Arthur J. Dommen, taking issue with something I wrote in "The Ravens of Long Tieng" (Oct./Nov. 1998), asserted that "the rules of engagement in Laos were among the U.S. Air Force's strictest." Compared to what? They certainly weren't stricter than those in force in North or South Vietnam. While flying over South Vietnam, I never fired a single 20-mm round without clearance from a forward air controller. And in North Vietnam, much of the targeting was controlled directly by the Joint Chiefs of Staff in Washington. In fact, certain targets were number-coded accordingly (JCS-16 is one I remember vividly). We didn't touch those unless specifically assigned.

To my knowledge, there were never JCS targets in Laos. On the contrary, parts of that country were open season all the time. I still have maps that show where we had free-drop zones. They show none in South Vietnam. We routinely conducted armed reconnaissance over Laos, dropping bombs as we saw fit, forward air controller or no forward air controller.

Mr. Dommen cites the Pentagon Papers and "other sources." Those sources must not have been aviators. As to Dommen's claim that Ambassador William H. Sullivan "closely monitored the air war," I suppose his close monitoring of the Phou Pha Thi debacle is one of those instances (see the book *Shooting at the Moon* by Roger Warner).

There were rules for bombing in Laos, but they were by far the most lenient in the Southeast Asian war. The Ravens, however, did their level best to bring organization out of the chaos that existed.

—Ralph Wetterhahn
Long Beach, California

"If you hear a scream shortly, it's because the maid washed his World War II bomber jacket."

Osprey Envy

"Extreme Machine" (Oct./Nov. 1998) reminded me of my experiences working at Bell Aerosystems. When some of Bell Aircraft went to Fort Worth and some remained in Niagara Falls, it seems that the two groups agreed on mutually exclusive charters: Bell Helicopter was to concentrate on Rotary Wing, while Bell Aerosystems would focus on Fixed Wing.

The two groups competed fiercely: The Bell Helicopter people considered the Bell Aerosystems X-22 (Rotating Ducted Fan) a rotary wing, while the Bell Aerosystems people considered Bell Helicopter's V-22 predecessor, the XV-3, an incursion on their fixed-wing charter. The competition was so intense that a research simulator was lost because the two companies could not cooperate on a V/STOL (vertical/short-takeoff-and-landing) study.

—Edward A. Stark
Montrose, Pennsylvania

Corrections

Dec. 1998/Jan. 1999 "It's About Time" (In the Museum): To determine its distance from the satellite, the GPS receiver multiplies, rather than divides, the signal's travel time by the speed of light.

"The Ultralight Tribe": The photograph on the bottom of p. 41 shows a Phantom, not a Flightstar.

Oct./Nov. 1998 "27,000 Seconds in Hell": Stability tests of the first "big throat" shuttle main engine (0208) were conducted at the Marshall Space Flight Center, not the Stennis Space Center.

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SOUNDINGS

Apollo 8 Whodunit

By all accounts, it was shaping up to be a lousy year. Robert F. Kennedy and Martin Luther King Jr. fell victim to assassins' bullets. Rioters clashed with police at the Democratic National Convention in Chicago. Thousands of soldiers died fighting in Vietnam.

Just a week before those tumultuous 12 months were committed to history, the crew of Apollo 8—the first people to escape Earth's gravity and the first to lay eyes on the whole planet—closed 1968 on an up note. "Every once in a while, something happens that just brings the whole country up to a new level and gets us out of the doldrums," Jim Lovell says, looking back on the day when he and fellow astronauts Frank Borman and Bill Anders held billions on Earth spellbound.

It's close to Christmas 30 years later when the astronauts reunite at Florida's Kennedy Space Center for a celebration sponsored by the National Space Club. Anders and Lovell—Borman is absent but sends best wishes via moonwalker Gene Cernan—are intent on solving the mission's two mysteries: Who chose the Bible passage they read that night, and who snapped the Earthrise photo?

Dangling in the blackness of space, Earth reminded Anders of a Christmas ornament. It was, after all, Christmas Eve. "Cernan took the picture," Anders fibs. "Yeah, by remote control," Lovell adds.

"Their camera jammed on Apollo 8. We took it on Apollo 10. We felt sorry for them," Cernan teases.

Anders, who didn't want Borman taking pictures of anything not on the official photo plan, says that Borman did indeed take the first Earthrise shot. "But that was a black-and-white picture," he says. "The picture that was commemorated on the [postage] stamp and has been the picture of popularity is the one I took. I had to fight the camera from Lovell to get it," he says.

Realizing they would enter lunar orbit on Christmas Eve—and warned by NASA's public relations machine that the world would be watching—the three men were racking their brains for the right words. As Lovell tells it, Borman's request for suggestions prompted former reporter and writer Joe Laitin to suggest a passage

NASA

from the Bible. "He picked up the New Testament, and his wife said, 'Look at the Old Testament, because the majority of people who will be listening to the Apollo 8 crew are not Christian.' "says Lovell. "And Genesis is the basis of many of the world's religions, so that's how it came to pass."

As the first live images of the desolate gray moonscape flickered on terrestrial TVs, the trio took turns reading aloud the first 10 verses of the book of Genesis. "In the beginning, God created the heaven and the earth...," Anders began. Borman closed with "...and God bless all of you, all of you on the good earth."

Listeners all over the world were mesmerized. "From the Southern Baptists, who had a big convention after our flight, we had about a hundred feet of a scroll with signatures thanking us for reading from the Bible," Anders recalls. "At the same time, we were sued in federal court by [noted atheist] Madalyn Murray O'Hair, who said we were mixing religion with state business."

—Beth Dickey

Cleared for...Liftoff?

Great Falls, Montana, Albuquerque, New Mexico, Las Vegas, Nevada, and Homestead, Florida, are among dozens of locales that will be sparring for bragging rights as a new fleet of reusable launch vehicles takes wing. These satellite-hauling RLVs won't drop spent rocket stages, so they won't need to take off over water to avoid populated areas. Just about any place with a runway that can accommodate high-performance jet aircraft is suitable.

That's good economic news in communities like Great Falls and Homestead, whose once-vital military bases are no longer needed for the nation's active defense. Great Falls' Malmstrom Air Force Base, scheduled to close in 2001, is earmarked as a possible port for the vehicle that Lockheed Martin is developing. Seventeen states, including Florida, are competing to land Lockheed Martin's NASA-subsidized VentureStar—not to mention the millions of dollars in construction expenses and thousands of jobs flying with it.

Homestead Air Reserve Base—still reeling from the double whammy of its devastation by Hurricane

UPDATE

AP PHOTO/NEWS2, CBS2

Live, From New York, It's: Chopper 4

The New Chopper 4, WNBC-TV's New York City news helicopter ("Live, From the Chopper...," Aug./Sept. 1998), made news itself last December when it made an emergency landing in the Passaic River in Newark, New Jersey. Pilot Terry Hawes had radioed a Mayday call during the evening rush hour, citing engine trouble. Witnesses cited "popping noises and flames" as Hawes put the $3.8 million twin-engine EC 135 Eurocopter into the river. Both pilot and reporter escaped relatively unscathed from the partially submerged helicopter.

Andrew in 1992 and its downgrading by the Pentagon the following year—more than likely will become the home port for Space Access LLC's air-breathing ramjet RLV. "The vehicle is flexible enough to be deployed from just about any airport in the world, [but] we would like for Homestead to be that site," says Ron Rosepink, flight operations chief for the Lancaster, California company.

But conservationists trying to rescue the Everglades have opposed the plan to breathe new life into Homestead. As 1998 drew to a close, Space Access was wrapping up work with the Air Force and the Federal Aviation Administration on an environmental impact study to be distributed for public comment early in 1999. They hope to prove that the base will be better for the Everglades as a spaceport than in its other possible incarnation: a reliever airport for Miami International. "It's high value, but not high volume," says Ed O'Connor, chief of Florida's commercial space agency.

—Beth Dickey

GRETCHEN LESSING MAXWELL

Scottish dignitaries chat in front of the memorial cairn at Arlington National Cemetery, outside Washington, D.C., prior to a ceremony commemorating the 10th anniversary of the bombing of Pan Am Flight 103. Bells were rung simultaneously at ceremonies here, at New York's Syracuse University, at Westminster Abbey in London, and in Lockerbie, Scotland, at 7:03 p.m., the moment of the mid-air explosion. President Clinton spoke at the December 21 service, assuring the families and friends that everything possible was being done to get the suspects to trial.

Fire From the Sky

For over 30 years, the National Reconnaissance Organization has built and run the U.S. government's spy satellites. Recently, it added a new mission: programming existing satellites to add the monitoring of fires and volcanoes to their recon duties.

Firefighters have been using satellite information since the 1970s, says NRO spokesman Rick Oborn. "When the northwest was having a rash of forest fires a few years ago," he says, "they were so big and smoky [fire chiefs] couldn't see where to send smokejumpers in. We took night photographs [with satellites] to see where the fires were actually located, then plotted them out to see where they might want to bulldoze firebreaks."

Oborn says a new Hazard Support System will replace most of the NRO's firefighting activities. By drawing data from multi-national environmental and weather satellites, HSS will be able to gather far more information than it could from NRO satellites alone. The main contribution of the NRO, which will serve as HSS systems engineer, is its three decades' experience with satellite data systems. "They're dealing with worldwide satellite data," Oborn says, "so somebody has to figure out how all the pieces come together: Where does the data come from, how does it get there, what kind of computer support it needs, what information goes out to which recipient."

Jim Devine, a science advisor at the U.S. Geological Survey, the agency in charge of the HSS, says the new system is expected to detect U.S. wilderness fires of four acres or less, track volcanic ash clouds (a flight hazard) around the world, and spot volcanic eruptions in their early stages. Devine says while there are other ways to spot eruptions, such as monitoring seismic tremors and gas emissions, only 10 percent of the world's volcanoes are currently monitored.

Most of the satellites in the system, Devine says, can provide HSS information almost as an aside: "We pull off a data stream that does not interfere with their primary mission; the data is basically noise." Each satellite alert will be evaluated by HSS operators. If an NRO satellite, for example, spots a fire, the information will be cross-checked with other satellites; if the fire is confirmed, the alert goes out. The goal is to make initial announcements in five minutes.

The prototype for the HSS system should be functional by next summer, when it will be field-tested to see if it produces too many false alarms. How to deliver the alert quickly is still unresolved. The National Interagency Fire Center in Boise, Idaho, which handles fires on federal land, will receive alerts electronically. Not every fire department can do that. "Uncertainty comes up when dealing with fires on private or state land," says Devine. "We're still developing procedures on how to get information to the right person."

And there are security problems to thrash out too: Currently, rather than distributing NRO satellite imagery hither and yon, agents copy the photographic data onto maps.

—Fraser Sherman

UPDATE

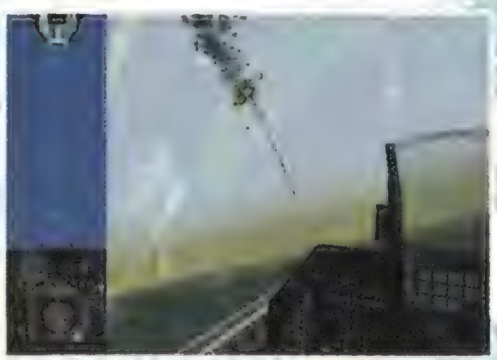
Farewells

Tetsuya Fujita, premier microburst and tornado researcher ("The Might of the Microburst," Aug./Sept. 1986), died last November at his home in Chicago. He was 78. The meteorologist devised the Fujita Scale for classifying the strength of tornadoes and was the first to propose that deadly invisible microbursts were the cause of a number of airliner crashes.

Test pilot Alvin "Tex" Johnston died last October from complications of Alzheimer's disease in Mount Vernon, Washington, at age 84. Johnston flew for Bell and Boeing and is best known for performing an impromptu barrel roll in Boeing's 707 prototype for an audience of airline industry executives in 1955 ("Dash 80," Apr./May 1987).

Beset by budget cuts, Great Britain's Royal Greenwich Observatory (Collections, Feb./Mar. 1994) was closed down last October. Britain's oldest scientific institution, founded in 1675 by King Charles II "for perfecting navigation and astronomy," moved from Greenwich to Sussex after World War II to escape London's light pollution. (The Greenwich facility continues to serve as a museum.) In 1990 the "Royal Ob" moved to Cambridge and its larger telescopes were moved to better viewing sites. As it was neither a true observatory nor in Greenwich, the modern facility's title and functions were viewed as questionable by its funding organization. With the closing, the Royal Ob's counterpart, the Royal Observatory in Edinburgh, Scotland, was named headquarters for British astronomy.

Technically, it's still a computer game.



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Garber's Metal Man

Many of the challenges of restoring historic aircraft at the National Air and Space Museum's Paul E. Garber Preservation, Restoration and Storage Facility in Suitland, Maryland, come from repairing the effects of the moisture, humidity, and advancing age that ravage the parts of even the mightiest combat aircraft.

But sometimes those parts aren't just corroded—they're damaged beyond repair, or missing altogether. That's when William P. Stevenson, a metalworker whose shop is tucked in a corner of Garber's Building 10, is called upon to turn raw metal into a replacement part accurate enough to have been fitted on the factory floor when the aircraft was built. "It seems like every airplane that goes through here has something bent, broken, or missing, and I end up making [a part], even if it's relatively insignificant," Stevenson says.

Stevenson was trained as an aircraft mechanic while serving with the Navy, where he worked on C-121 Super Constellations and Grumman S-2F Hunter/Trackers. He got his most extensive experience on H-34 helicopters; that work included an 18-month stint at the McMurdo Ice Station in the Antarctic. Stevenson and the others at the station were resupplied by ski-equipped LC-130s that periodically landed on the vast expanse of the Ross Ice Shelf.

After returning to the more reasonable climate of the Washington, D.C. area, Stevenson traveled to Tulsa, Oklahoma, where he studied metalworking and began to gravitate toward jobs in which he could use those skills. "I always liked working with metal more than changing parts on an engine," Stevenson says. "I'd rather make something." Stevenson used those new abilities when he fabricated two new landing gear doors for the Smithsonian's Supermarine Spitfire—using borrowed gear doors as templates—while he worked at an aircraft maintenance company in Gaithersburg, Maryland, that had contracted to do the work. In 1976, while working at the Marine Corps Aviation Museum in Quantico, Virginia, which was restoring the Smithsonian-loaned Boeing FB-5, Stevenson's masterful work attracted the attention of Smithsonian restoration staff. Soon after, he was recruited by Walter Boyne, the future director of the newly formed National Air and Space Museum. (The FB-5 remains at the Marine Corps museum; the Spitfire is on display in NASM's World War II gallery.)

Today, Stevenson's main project is the creation of a fuel tank for the Museum's Nieuport 28, a French World War I fighter. Next to his workbench lies an original fuel tank, donated by a private restorer, who is rebuilding his own example of the aircraft to flying status. As is the case with many restorations, the donated tank came to the Museum by way of a little deal-making: In exchange for the real tank, which is corroded to the point that it couldn't be used in an operating aircraft, Stevenson is making a replica (below) that the donor (who wishes to remain anonymous) can use for his Nieuport.


ERIC LONG

Stevenson, whose expertise as an aircraft mechanic constantly guides his metalwork, is following the donor's instructions and copying the original tank exactly, despite the fact that the tank could be much improved with a few modifications. The internal baffles, which prevent the fuel from sloshing back and forth as the aircraft maneuvers, have openings that are too small to allow fuel to transfer effectively between the chambers, possibly keeping some fuel from being drawn into the engine. However, the donor is interested in absolute authenticity and will get exactly what he wants, down to the use of a rare mixture of lead and tin called turnplate that was used to construct the original tank. Stevenson obtained the material from one of the few companies in the world that still produce it. The tank was built with the help of Garber machinist George Vencelov, who fashioned a copy of the valve through which the fuel will flow. Because of the natural relationship between their talents, the two men often work on projects together. Stevenson,

Vencelov, and chemist Bayne Rector are not assigned to particular projects, but rather supply their expertise as needed to a variety of aircraft restorations.

The conflict between display quality and airworthiness has become more evident recently, as Garber restorers focus more on preserving originality as much as possible. Stevenson stands before the wing of the only remaining Japanese Aichi A6A1 Seiran, a submarine-borne floatplane built to attack the Panama Canal during World War II; the wing-fold mechanism is being disassembled and cleaned, and many of the wing's original—and now distinctly non-airworthy—nuts, bolts, and assorted hardware are being reused, because every piece, down to the lowliest bent cotter pin, is now viewed as a historic artifact. "In the last 10 years, there has been more awareness of how restorations should be done," Stevenson says. "Instead of stripping the whole aircraft, anything that can be saved is saved."

Fabricating the Nieuport 28's tank was made easier by having an original example to take measurements from. In other cases, Stevenson must re-create a part while lacking even the most basic drawings or specifications. The Museum's Pitts Special, under restoration at Garber since 1996, entered the Museum's collection missing its wheel pants—metal fairings for non-retractable landing gear. Stevenson had to rely on period photographs—none taken with consideration for a metal fabricator working years later. As other workers recovered and repainted the Pitts, which is the second ever built and is known as *Little Stinker* (see "Vintage Skunk," In the Museum, Aug./Sept. 1998), Stevenson labored to re-create the aircraft's wheel pants by taking careful measurements from existing photographs and drawings, scaling them up on an office copier, and translating them into plywood molds around which the metal was shaped. The molds themselves are sanded beautifully smooth and gleam with varnish. However, to the aircraft restorers at Garber, the real beauty comes from the finished wheel pants, fabricated from the exact aluminum grade used for the originals and painted in green primer as they await imminent fitting to the Pitts' landing gear.

Stevenson enjoys the varied nature of his work and the experience he gains from it: His assignments have even included repair of a metal sculpture that was damaged in transit before it was to go on display at the Smithsonian's Hirshhorn Museum and Sculpture Garden. Often he's working on several projects at a time, plus helping with building maintenance and upkeep of Garber's massive metal-working presses and equipment, but the pace suits him just fine. "The only way I intend to leave here is in a box or by retiring," Stevenson says. "It keeps me going."

—*John Sotham*

Steering by Starlight

NASM

Want a better sense of how to get there from here? Check out the Einstein Planetarium's newest show, "And a Star to Steer Her By," which is understatedly narrated by British actor Sir Alec Guinness. This latest offering from the Museum's planetarium outlines the problems faced by 17th and 18th century mariners in navigating the seas. Sailors traveling in the northern hemisphere could rely on Polaris, the North star, to determine their latitude, but fixing their longitude, or east-west position, was more difficult, and the methods they devised were often cumbersome. The show gives a timeline (left) of instruments used over the years, such as the astrolabe, sextant, and chronometer, and winds up with a description of how modern navigation is done with artificial stars, or satellites, such as those that make up the Global Positioning System.

—*Diane Tedeschi*

Museum Calendar

Except where noted, no tickets or reservations are required. To find out more, call Smithsonian Information at (202) 357-2700; TTY (202) 357-1729.

February 13 Family Night: "African-Americans in Aviation." The night will kick off at 7 p.m. with a performance about black aviator Bessie Coleman. Visitors can also talk to Tuskegee Airmen. Registration: $15 adults, $10 children. To register, call (202) 786-2108.

National Air and Space Society

As a Founder Member you can help support the most significant effort in the National Air and Space Museum's history: the new Dulles Center, to be built at Washington Dulles International Airport. For information, call (202) 357-3762, or write to: The National Air and Space Society, NASM, Room 3608, MRC-310, Smithsonian Institution, Washington, DC 20560; e-mail: nass@sivm.si.edu

February 27 Monthly Star Lecture: "The Circle of Animals—Tales of the Zodiac." Join staff astronomer Sean O'Brien to learn how the zodiac system arose from the imaginations of ancient astronomers. Einstein Planetarium, 6 p.m.

February 27 National Air and Space Society Lecture: "Aerobatic Flying, Patty Wagstaff Style." Wagstaff will discuss her career in aviation, first as a champion aerobatic pilot and now as a stunt pilot. To reserve your free tickets, call (202) 357-3762. Langley Theater, 8 p.m.

Curator's Choice

Once a week a Museum curator will give a 15-minute talk about a subject of interest. Feb. 3, "William Powell"; Feb. 10, "Chauncey Spencer and the Lincoln Paige"; Feb. 17, "George Carruthers and Apollo"; Feb. 24, "Astronaut Guy Bluford." Meet at the Gold Seal in the Milestones of Flight gallery at noon.

AWARD NIGHT

MARK AVINO

On November 5, National Air and Space Museum director Don Engen (right) presented the 1998 NASM Trophy Award for current achievement in aerospace technology to Tony Spear (center), project manager of the Mars Pathfinder team. To the left of Spear is master of ceremonies and former "Good Morning America" host David Hartman. The award ceremony and dinner reception were made possible by a donation from Lockheed Martin.

Signatures From Earth

During my nearly four decades at NASA's Jet Propulsion Laboratory in Pasadena, California, I have designed missions to most of the planets in our solar system. It has been exciting and moving to watch as these missions returned close-up pictures of worlds we once saw only as fuzzy spots. But there's one experience in particular that stands out in my mind. It involved the ongoing Cassini-Huygens robotic mission to Saturn and its large moon, Titan, as well as a unique interaction with people from around the world.

On prior deep-space missions, many of us who worked on these projects were given the privilege of having our signatures flown aboard small aluminum plates attached to the spacecraft. A single plate could hold about 900 scaled-down signatures. Six plates were flown aboard each Voyager spacecraft, 11 aboard Galileo. As our signatures made the long journey in place of ourselves, we were proud to be part of a great adventure. It stoked our fires to succeed.

Then, in the 1980s, the CD-ROM digital storage disk arrived. It was small and could store 650 megabytes of information—enough space for perhaps a million or more signatures. This was a thousand times the capacity available on each plate flown on past missions. Cassini program manager Richard Spehalski decided in late 1995 to offer the public the chance to have their signatures make the seven-year flight to Saturn aboard the Cassini spacecraft. Since my duties as the program's science and mission design manager included public outreach, he asked me to make this happen.

I announced the offer on the Cassini Web site (www.jpl.nasa.gov/cassini). People merely had to sign a postcard and send it to JPL. The response was overwhelming. Cards began arriving from around the globe—as many as 35,000 signatures a week. The mail came from individuals, families, often entire schools. Signatures came from the very young, just learning to write, and the very old, whose hands were no longer steady. Some even sent their dogs' and cats' paw prints.

We received signatures from film and TV stars, including Patrick Stewart and the crew of the movie *First Contact* as well as Chuck Norris. We received a signature from Australian Mary Cassini, a distant descendant of Jean Dominique Cassini, the astronomer after whom the mission was named. One poignant set of signatures came from Hillary Moore, who had died of congestive heart failure at the age of 15. In a cover letter, her father had asked if the Cassini program would send a full page of her signatures, written in her school notebook during happier times. I knew that the guideline of "one signature per person" would simply be waived in this case.

We needed help in sorting, counting, and scanning all of this mail. Volunteers from the Pasadena-based Planetary Society came to our rescue, toiling for more than a year to finish the job. One steadfast volunteer, Joseph Oliver, logged an incredible 334 hours. I got to know Joe pretty well, but in all the time he worked with us I saw him only once remove his favorite knit ski cap.

The volunteers regularly delivered small storage tapes to JPL, where the contents were prepared for transfer to either a CD-ROM or a DVD, or Digital Video Disk. Developed in the mid-1990s, the DVD can hold much more information than a CD-ROM. To reduce the workload on the volunteers, I ultimately decided to use a single DVD. At final count, we had received 616,420 signatures from 81 countries.

Since I spend much of my non-JPL time working as a digital artist, the task of creating a design for the face of the disk was something I especially relished. After toying around with a few ideas, I formed an approach that would allow the display of many different mission elements.

Flags from the 28 countries that provided the greatest number of signatures (99.5 percent of the total) encircle the disk near its edge. The United States, with the most signatures—542,020—appears in the 12 o'clock position, while countries with successively lower numbers follow in clockwise order, ending with Thailand. (A few countries—Bermuda, El Salvador, Ghana, Qatar, Tanzania, and Zimbabwe—contributed only one signature each.)

Inward from the ribbon of flags are six feathers. I chose this design element because of its ability to represent both the power and beauty of flight and the historic quill pen, with its link to some of humanity's greatest documents. The feather is that of the broad-ranging golden eagle. To various Native American tribes, eagles have long been symbols of clear sight, perception, strength, power, the sky, and the divine spirit beyond.

Inward from the feathers, I added the names Cassini and Huygens, the namesakes of the mission and its probe to Titan, respectively. Jean Dominique Cassini and Christiaan Huygens were 17th century scientists known for their observations of Saturn and its moons and rings. Cassini discovered four of Saturn's

moons (Iapetus, Rhea, Tethys, and Dione) as well as the large gap between the planet's A and B rings now known as the Cassini Division. Huygens was the first to deduce that Saturn was surrounded by a ring, and he discovered Titan—the second largest moon in the solar system, larger than the planets Mercury and Pluto. Cassini's and Huygens' signatures, taken from letters each had written in the late 1600s, are among those on the DVD.

A few months after the Cassini spacecraft arrives at Saturn, in July 2004, the European Space Agency's Huygens probe will separate from it and coast to Titan. On the design, the Cassini spacecraft appears at two o'clock and the Huygens probe at eight o'clock. The spacecraft, which will orbit Saturn for the duration of the four-year mission (and well beyond that), is the size of a school bus and carries many sensors to examine the planet, its rings and icy moons, its magnetosphere, and of course Titan. The large white antenna on the orbiter will receive instructions from Earth and beam back data gathered by both the orbiter and the probe.

The image of Earth that appears in the background was captured in 1991 by the ESA Meteosat 3 geostationary weather satellite. Over 90 percent of the signatures we received were from people living on continents visible in this image. One can just make out California, where the spacecraft was assembled and tested, as well as Florida, where it was launched.

The orange ball at four o'clock is a photograph of Titan taken from the Voyager 2 spacecraft in 1981. Its hazy, brownish-orange atmosphere of nitrogen, methane, and a complex array of carbon-based molecules hides a frigid surface that may contain subsurface reservoirs—perhaps even lakes—of liquid ethane and methane. Conditions on Titan may resemble those on Earth before life began, but we must wait until the probe reaches it, in late 2004, to get our first close look at the moon.

At the center of the design is a Voyager 2 picture of Saturn and its spectacular rings taken from a range of 13 million miles. Unlike the solar system's inner planets, Saturn does not have a rocky surface but is made up mostly of gases, which become denser and hotter from cloud tops to interior. Saturn is believed to have a core of liquid rock about the size of Earth beneath a layer of liquid hydrogen and helium.

As for Saturn's magnificent rings, they march in near-circular orbits about their captor in a vast, thin sheet and probably consist of loosely packed balls of water ice, with small amounts of rocky material and traces of oxidized iron. A major objective of the mission is to search for clues to how the rings formed and how they function, and to forecast their future.

With launch scheduled for October 1997, the DVD was mastered in late May of that year. The project cost less than $5,000. Ten copies of the disk were made: one for the spacecraft, one for JPL, and the remainder for display in museums around the world.

During a ceremony at Florida's Kennedy Space Center that August, just before the Cassini spacecraft was ready for rollout, the flight disk was placed between two pieces of aluminum that would provide protection from micrometeoroid impacts. The assembly was mounted to the side of the spacecraft and covered with a specially decorated patch of thermal blanket.

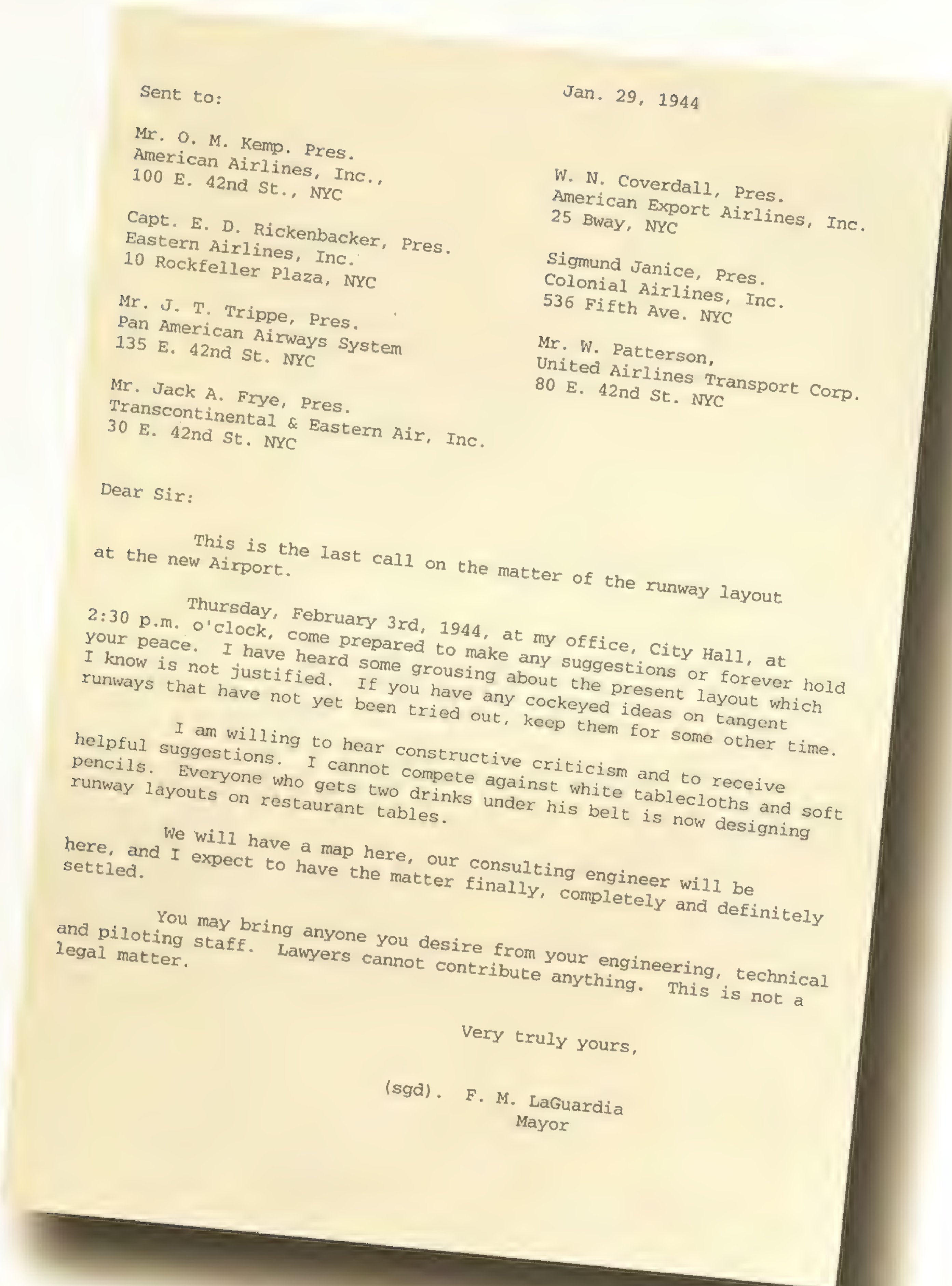
Two months later, just before dawn, I watched as the Cassini spacecraft lifted off from its Florida launch pad atop a Titan-Centaur rocket. It rapidly climbed, punched through a low cloud deck, and headed downrange. The six-ton spacecraft was precisely delivered to its Earth departure vector—as were the hundreds of thousands of signatures.

There are many reasons for this outpouring of human signatures. Just as each fingerprint is unique, so is each signature. We are reminded of pioneers who left their names or initials chiseled in stone. Some of us dream of escaping Earth and venturing into the cosmos. Sending our signatures is a way of making such a journey, and we can pass this story of our "signing aboard" on to our descendants. Each of us has extended his reach to that point of light in the night sky known as Saturn.

—Charley Kohlhase

NASA

The author (left) and Cassini program manager Richard Spehalski prepare to send the signature disk packing.



Sent to:

Jan. 29, 1944

Mr. O. M. Kemp. Pres.
American Airlines, Inc.,
100 E. 42nd St., NYC

Capt. E. D. Rickenbacker, Pres.
Eastern Airlines, Inc.
10 Rockfeller Plaza, NYC

Mr. J. T. Trippe, Pres.
Pan American Airways System
135 E. 42nd St. NYC

Mr. Jack A. Frye, Pres.
Transcontinental & Eastern Air, Inc.
30 E. 42nd St. NYC

W. N. Coverdall, Pres.
American Export Airlines, Inc.
25 Bway, NYC

Sigmund Janice, Pres.
Colonial Airlines, Inc.
536 Fifth Ave. NYC

Mr. W. Patterson,
United Airlines Transport Corp.
80 E. 42nd St. NYC

Dear Sir:

This is the last call on the matter of the runway layout at the new Airport.

Thursday, February 3rd, 1944, at my office, City Hall, at 2:30 p.m. o'clock, come prepared to make any suggestions or forever hold your peace. I have heard some grousing about the present layout which I know is not justified. If you have any cockeyed ideas on tangent runways that have not yet been tried out, keep them for some other time.

I am willing to hear constructive criticism and to receive helpful suggestions. I cannot compete against white tablecloths and soft pencils. Everyone who gets two drinks under his belt is now designing runway layouts on restaurant tables.

We will have a map here, our consulting engineer will be here, and I expect to have the matter finally, completely and definitely settled.

You may bring anyone you desire from your engineering, technical and piloting staff. Lawyers cannot contribute anything. This is not a legal matter.

Very truly yours,

(sgd). F. M. LaGuardia
Mayor

This letter was discovered by former Federal Aviation Administration operations manager Jim Davis in a janitor's trash cart in the agency's Washington, D.C. headquarters in 1989. Davis cannot verify the authenticity of the letter, which he believes was originally sent as a telegram—there are a number of errors in the address list and the sender's middle initial is incorrect—but people in the know say it sounds like the sort of ultimatum Fiorello LaGuardia would issue. The airport in question is New York's Idlewild, which in 1963 became John F. Kennedy International.

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Splendors of Western Turkey: *May 14-30.*

French Waterways: From Paris to Burgundy. May 21-June 1. Aboard the Anacoluthe.

Jewels of the Aegean: Crete, Rhodes & Santorini. *May 25-June 6.*

Journey through Central Europe: *May 26-June 7.*

The Elbe River Cruise (Germany): *May 26-June 8.* Aboard the *M.V. Konigstein.*

Along the Ancient Coast of Turkey: *May 26-June 16.* Aboard the *Panorama.*

Celtic Treasures (Wales & Ireland): *June 9-20.*

Journey of Odysseus: *June 13-27.* Aboard the *Clelia II.*

In Search of and Empire (Rome, Tuscany & Provence): *June 15-26.* Aboard the *Cezanne II.*

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689
689

OLD 'HOG, NEW TRICKS

New electronics and new missions gave the A-10 Thunderbolt II a second chance.

by William L. Smallwood

Photographs by Chad Slattery

In a span of just five years during the 1970s, the Air Force took delivery of a trio of aircraft types that would provide the heart of the service's combat capability for decades to come. The Mach 2-capable F-15 Eagle, introduced in 1973, is the Air Force's premier air superiority fighter until it is replaced by the F-22 Raptor in the next millennium. The sleek F-16 Fighting Falcon was fielded in 1978 and today serves in a number of roles, including ground attack and the suppression of enemy air defense.

And then there was the "Warthog."

Decades after swept wings and pointy noses became standard attributes for combat aircraft, the 1976 appearance of the A-10—soon to be known as the Thunderbolt II—on Air Force flightlines was not without controversy. Straight, thick wings and a blunt nose. A top speed barely equal to that of a World War II-era P-51 Mustang. Twin tailpanes the size of barn doors, and two turbofan engines set high on the rear fuselage like afterthoughts. However, there was a method behind the A-10's assault on the eyes. Based on the lessons learned from Vietnam, where fighters like F-105s and F-4s were pressed into ground attack missions, the A-10 was designed from the start for ground attack, and built to withstand a tremendous amount of damage. And at a time when the United States had spent 30 years rehearsing for a highly scripted war with the Soviet Union, the A-10 was created for a single, critical role: to kill tanks.

Front and center: Intent on getting the A-10 Warthog's tank-killing 30-mm Gatling cannon as close to the centerline as possible, designers muscled the nose gear strut out of the way (opposite). If hydraulics are lost, all three gear can freefall into place.

In those days, hordes of Soviet tanks were poised near the Fulda Gap in the former West Germany and other European invasion corridors. Awaiting them would be hundreds of A-10s whose mission was to fly at near tree-top level and attack with both an array of missiles and the Warthog's internal 30-mm Gatling gun, which can fire up to 70 devastating, two-pound depleted-uranium shells per second. But despite the Warthog's firepower, attacking through streams of Soviet anti-aircraft fire wasn't a pleasing proposition. The aircraft, which were expected to suffer heavy

RICK LLINARES

After the Gulf War, A-10s began to shed their mottled green camouflage—meant to help them blend into the European countryside—and got a new gray scheme (left) that includes a phantom canopy painted on the belly. When honing their delivery skills, A-10 pilots drop small practice bombs (above right). For gun practice, they shoot at bull's eyes (bottom).

losses, would merely blunt an all-out Soviet attack while friendly forces massed. "They used to joke that we were a speed bump," said Lieutenant Colonel Steve Ruehl, who, as a young lieutenant was stationed near one of the former invasion corridors.

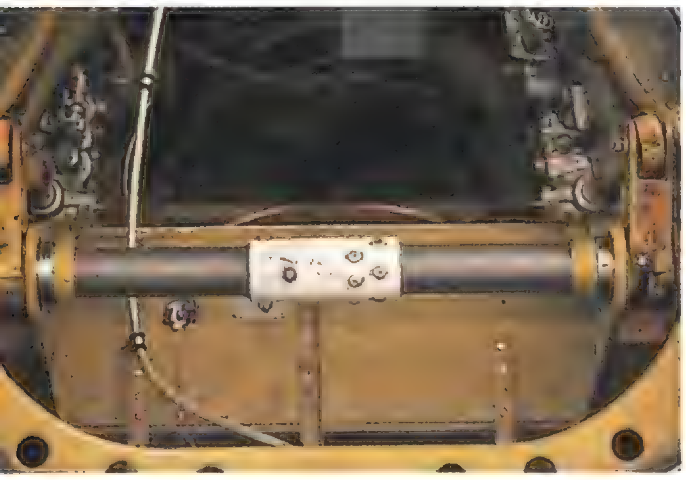
The need for a tank-killing aircraft was never in doubt, but whether the A-10 was up to the job was often debated. Air Force leaders openly discussed replacing A-10s with a ground attack version of the F-16, and as the Soviet Union began to unravel prior to the Gulf War, it was rumored throughout the Air Force that A-10s were heading to the boneyard—with the cold war ending, they were no longer needed in the inventory. This rumor has never been officially confirmed, but real evidence exists: Training for new A-10 pilots was winding down, and instructors teaching at the A-10A Fighter Weapons School at Nellis Air Force Base in Nevada were told they would be looking for new assignments in the near future.

But the Warthog's spectacular performance in Operation Desert Storm—during which A-10s killed thousands of trucks, artillery pieces, and other vehicles—would show the wisdom of the aircraft's design and point the way to new missions. A-10s even bagged two helicopters, which, as gleeful Warthog supporters noted, was exactly two more aerial victories than nimble F-16s scored. The Warthog proved to be versatile, survivable, and reliable.

During the autumn of 1990, as the buildup to the war started, it became apparent that changes were needed in A-10 doctrine, which was based on fighting the Soviets in Europe, and although it wasn't clear at the time, those mission changes would begin to define the

A-10's role after the war. Since the Army was evolving into a night fighting force, Colonel Irwin "Sandy" Sharpe, an A-10 commander, understood the implications for the Warthog. After consulting with coalition air commander Lieutenant General Charles Horner, Sharpe, with Horner's concurrence, induced one of his squadron commanders, Lieutenant Colonel Rick McDow, to volunteer for the new mission. The pilots were apprehensive, but McDow had been a Vietnam POW and was highly respected as a combat leader, so, with deep misgivings, they went along.

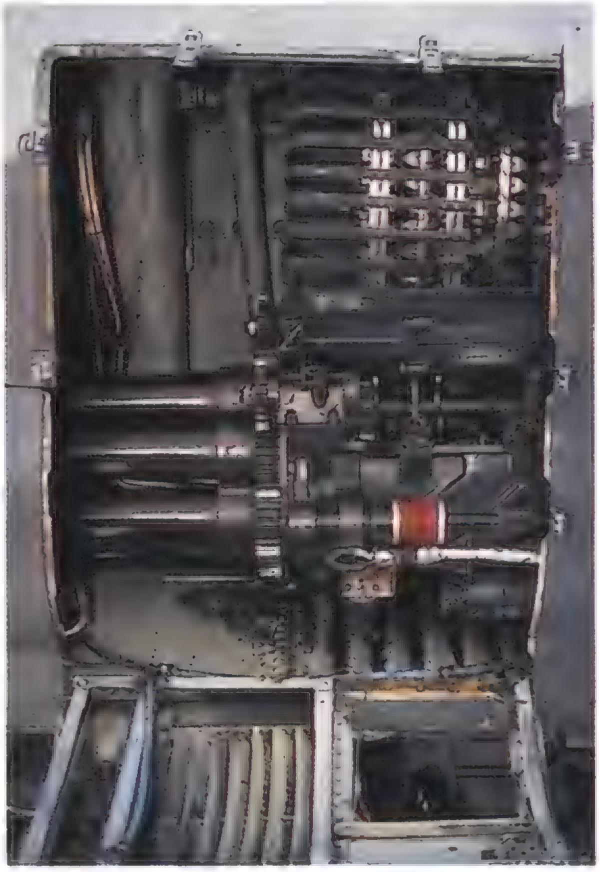
Flying during the war in total blackness, they used six-inch monitors in



Air Force maintenance personnel are all over this Warthog during its 400-hour phase inspection (above). They change time-sensitive components, fit newly rebuilt engines if necessary, and check flight control linkages and cables (bottom, left). The A-10's inch-and-a-half-thick windscreen is bullet-proof and made from a glass-and-plastic sandwich (left).

The "Warthog"

The Fairchild A-10 was designed and built around a General Electric 30-mm GAU-8/A Gatling cannon that fires armor-piercing rounds made from depleted uranium. The Warthog's airframe, which features a titanium "bathtub" around the cockpit, can survive punishing damage.



The General Electric GAU-8/A cannon consists of three main parts: the ammunition drum, drive system, and barrel assembly (above, left to right). During loading, the aircraft's auxilliary power unit energizes the drive system (right), which draws new rounds into the drum and expels spent shell casings into the container attached to the servicing cart (top).

their cockpits that were linked to the infrared seekers in their Maverick missiles as an improvised imaging system. When pilots had fired all their Mavericks, they attacked by the light of World War II-type parachute flares. McDow's squadron, along with a second squadron that "volunteered" later, killed scores of tanks and artillery pieces. And, of greater significance to the commanders who were beginning to admire the new "Nighthogs," they fought the air campaign without casualties. Indeed, in a theater where Vietnam veterans claimed the anti-aircraft fire to be the worst they had ever seen, not one of the two Nighthog squadrons returned from combat with so much as a single bullet hole.

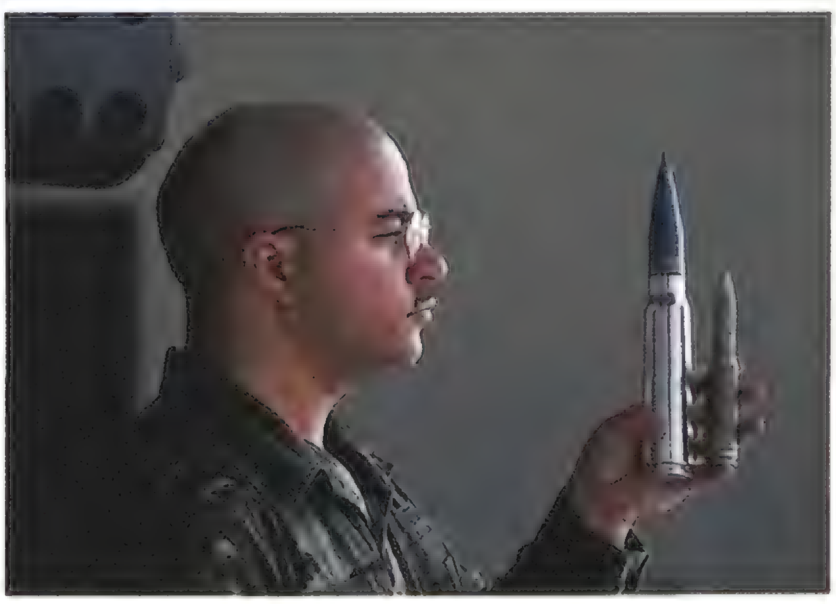
Such successes won over many in what the pilots call the "pointy-nose, Mach-snot" fighter fraternities, including Horner, who jokingly derided the A-10, despite the fact that his own son was then a Warthog pilot. Yet, about midway through the air campaign, when the A-10 was demonstrating its versatility against the Iraqis, Horner confessed at a battle staff meeting, "I take back all the bad things I have ever said about the A-10. I love them! They're saving our asses!"

If Desert Storm was eventually to

point the way toward the A-10's future, it also vindicated its past. Gulf War A-10 pilots drank toasts (from their forbidden liquor supply) to the engineers who had designed the survival features that enabled several of their buddies to get home with crippled airplanes. The cockpit is encased in a titanium "bathtub," and redundant systems, including hydraulics, are located in different areas to help increase the odds that a backup will survive a strike from ground fire. The engines, mounted high above the fuselage on pylons, feature quiet, high-bypass General Electric TF34-100As that are easy to change and maintain in the field and whose exhaust is directed above the horizontal stabilizers to shield the craft from ground-based infrared missiles. The cockpit windscreen is one and a half inches thick and bulletproof. And each of the double tails is capable of controlling the airplane if the other is lost. All fuel is carried in tanks that are inboard of the landing gear so that entire portions of the wings can be struck without risk to the tanks. The fuel tanks themselves are protected by efficient fire extinguishing systems. "When we were in Germany, a couple of our airplanes had fuel tank fires that we didn't even know about until the crew chiefs discovered carbon residue in the vent pipes," says retired Colonel Steve Kaatz.

Two Desert Storm A-10 pilots, with their aircraft's hydraulic systems completely inoperative from battle damage, managed to land safely using the manual reversion system, which disconnects the flight controls from the hydraulics and allows the airplane to be flown, with great effort, by control cables. In addition, one pilot landed with two of his three wing spars blown away and the third one damaged. Another pilot, Colonel Bob Efferson, made it back after four exploding rounds from a 57-mm anti-aircraft gun put 378 holes in his airplane—damage that would probably have killed him had he not been surrounded by titanium armor.

Big bang: The 4,000-pound GAU-8/A can fire 70 rounds per second (top). Staff Sergeant Anthony Alfred compares the A-10's 30-mm round and a 20-mm round used by aircraft like the F-15 and F-16 (below).



Today, the Warthog, which was designed as a basic ground attack platform, has been upgraded with an array of new systems and capabilities that take it beyond the aircraft's original design. "The A-10 we are flying today is not the same airplane that went to war in the Gulf," Ruehl says. "I wish they would call it the A-10P [instead of the A-10A] so people would get the idea of how much it has been improved."

The first key improvement added what might seem like basic equipment on any modern warplane—a computer—in the form of the Low Altitude Safety and Targeting Enhancement (LASTE) system, which had begun to be fitted shortly before the Gulf War but was still too new to be used in combat. However, the conflict was to underscore the need for a system that allowed the A-10 to deliver its weapons from higher altitudes. "Before the war, if we flew above 1,000 feet we expected to get a nosebleed," says Major Dave Feehs. In the Gulf, however, pilots began contemplating the heavy volume of missile and antiaircraft gunfire that the Iraqis would unleash at them. The pilots went to war at altitudes above 12,000 feet—above the worst of the gunfire and out of range of most of the deadly shoulder-fired, surface-to-air missiles. At these higher altitudes, their strikes were less accurate, but they compensated by dropping more ordnance. To destroy something like an artillery battery sometimes required a spread of 12 bombs from a two-ship element.

Desert Storm pilots had been trained in the traditional, pre-LASTE manner, which involved many hours of studying the science of dropping bombs; this required analyzing a host of variables, including ambient air temperature, density altitude, angle of dive, terminal velocity, and wind drift so that the appropriate settings could be set into the target designator in the A-10's head-up display. The pilots all knew, of course, that they were eventually going to compute these bomb-

ing solutions during the scant seconds when their Warthog's nose was pointed at the ground, after they had rolled in on the target and were "in the chute." However, just when the student pilots were beginning to master this convoluted procedure, the instructor would sometimes try a little humor and announce that he was now ready to introduce an even more complicated method of obtaining bombing solutions: T-LAR, or "That Looks About Right."

Such mental calculations were hard enough in training but proved to be especially challenging in actual combat and while diving from unheard-of altitudes, which introduced even more error. There was no technology to rely on, just Kentucky windage. "Because of those ferocious winds, dropping bombs manually in that war was an art form," says Major Jim McCauley.

The LASTE system puts an end to uncertainty. It's heart is a computer similar to that found in another sometimes-derided ground attack aircraft, the A-7 Corsair II. The system computes a continuously updated impact point that appears on the head-up display. The pilot simply overlays the indicator on the target during the aircraft's delivery dive. A pilot places his head-up display designator on the tar-

Night-vision goggles now let pilots use the A-10 to fly and fight at night, and new models promise unrestricted vision and greater comfort for Warthog drivers like First Lieutenant Shawn McManus (right). In an era of "glass cockpits," the A-10's instrument panel is a handsome throwback.

get and the LASTE tells him when to release his weapon.

"The old stick-and-rudder airplane has been computerized—that's the essence of the change," says Lieutenant Colonel John Condon, who is now Deputy Commandant of the Fighter Weapons School at Nellis Air Force Base in Nevada. "Prior to LASTE it took a thousand-hour pilot who had been down the chute 300 or 400 times to be good enough to get good bombs, and new pilots were lucky to hit the Earth." Condon was in the first two-ship element that took off for combat in the Gulf War. "Now we can put a new guy in the airplane, and because of the LASTE system he can get very, very accurate deliveries. If we were going after tanks in revetments like we did in Iraq, we would not miss. A miss now is very rare—and I'm talking dumb bombs [not laser-guided] from 14,000 feet... Being 'top gun' doesn't mean all that much anymore. Accuracy now depends more upon the individual jet and how tight its system is aligned. A young lieutenant in a good jet can go out to the range and do as well as a high-time pilot."

Captain Diane Ridgley requested to fly the A-10 when she graduated from pilot training, and has been flying the 'Hog for two years (left). Lieutenant Colonel Steve Ruehl has seen it all: While training to find and attack targets, he began flying the Warthog when the detection technology of choice was the naked eye. Today, he sights bad guys with night-vision goggles (bottom, left.)

To Major John Marks, the most exciting thing about LASTE is the way it improved the effectiveness of the A-10's massive 30-mm Gatling gun. "Before LASTE, all we had was the equivalent of an iron sight on a rifle," he says. "At long range, we had to allow for elevation. At short range, we had to keep from overshooting. But now, with LASTE doing the calculations, we just put the pipper on the target and we get good hits at ranges we never dreamed of trying before," he says. "We routinely shoot targets at 15,000 feet slant range and that's only because that's how far the LASTE system computes. The bullets are still effective beyond that range, and we're now looking at upgrades that will allow us to fire from greater distances."

LASTE increases the gun's effectiveness through the Precision Attitude Control (PAC), which is linked to the A-10's Stability Augmentation System (SAS). The SAS, already standard equipment on the A-10, synchronizes pitch and yaw inputs and makes the flightpath smoother. However, the A-10 is a naturally stable aircraft, unlike the F-16, which is uncontrollable without flight control computers. With the addition of LASTE, the SAS becomes useful not just for flying but for keeping the gun pointed at what the pilot is shooting at, despite the violent forces the gun imparts on the airframe as it fires. Pulling the A-10's trigger to the first detent activates the PAC system, which dampens the SAS's pitch inputs, allowing the pilot to fine-tune the aim. The second detent fires the gun and activates the SAS to counteract any stick inputs the pilot makes. "You have very little ability to change your aim when you pull

the trigger... ." Marks says. "You can overpower it, but you change the aim a lot. Better to be pointed exactly where you want it when you pull the second detent, because that is where the gun is going to fire... Before we had the PAC system, you would get your aim point close, but wouldn't delay firing... [you'd] adjust your aim after firing. Now you have to take a few extra breaths and get it exactly where you want it before you start shooting. Before LASTE, the recoil and barrel rotation caused the airplane to jump around—it was very difficult to keep the sight on the target... I remember from the war one of the toughest things in killing a tank with the gun was to keep the bullets concentrated after you started firing. That is not a problem now. The PAC system freezes the nose of the airplane where it was when you first pulled the trigger. That keeps the bullet stream concentrated."

In addition to adding an autopilot that makes long deployment flights more bearable, LASTE also provides a greater measure of safety for pilots as they dive at high speed toward the ground to attack targets. The Ground Collision Avoidance System (GCAS) which is tied into a radar altimeter, provides a shrieking, synthesized voice that urges the pilot to pull up. The GCAS provides a measure of safety to a task-saturated pilot unaware that he is imminently close to hitting the ground.

Another key improvement to the A-10, giving the pilot night vision goggles, adds a feature the aircraft's designers hadn't planned on. Before Desert Storm, pilots trained at night but their focus was on daytime operations. And as with LASTE—the need for which was proven in Desert Storm—the Warthog's new night capability was a natural progession from its performance over Iraq, when pilots used the imaging sensors on their Maverick missiles to see through fog, darkness, and smoke.

Today, NVGs vastly improve on Gulf War ingenuity. Experimentation with NVGs started immediately after the war, and the goggles are now standard Warthog equipment. However, NVGs don't come without drawbacks. The current models allow only a 40-degree field of view, which seriously hampers the wide view possible from the A-10 cockpit and can be troublesome for a pilot as he maneuvers close to the ground searching for targets. Normal peripheral vision is greater than that provided by the goggles, so pilots must constantly sweep their heads to compensate, and that results in sore necks.

Vertigo is also a potential complication when visibility is bad enough to obscure the horizon. To guard against a sudden failure of the goggles, pilots must stow them in the cockpit during takeoff or five minutes before landing, and must take them off within a mile of an aerial tanker, because the tanker's lights would be amplified so much they would wash out the wearer's vision.

NVGs work by amplifying ambient light, which most often comes from the moon but can come from "cultural lighting"—illumination from cities and towns. A slight bit of moonlight is ideal—looking at a full moon through NVGs is as blinding as looking at the sun. During moonless nights, an A-10 forward air

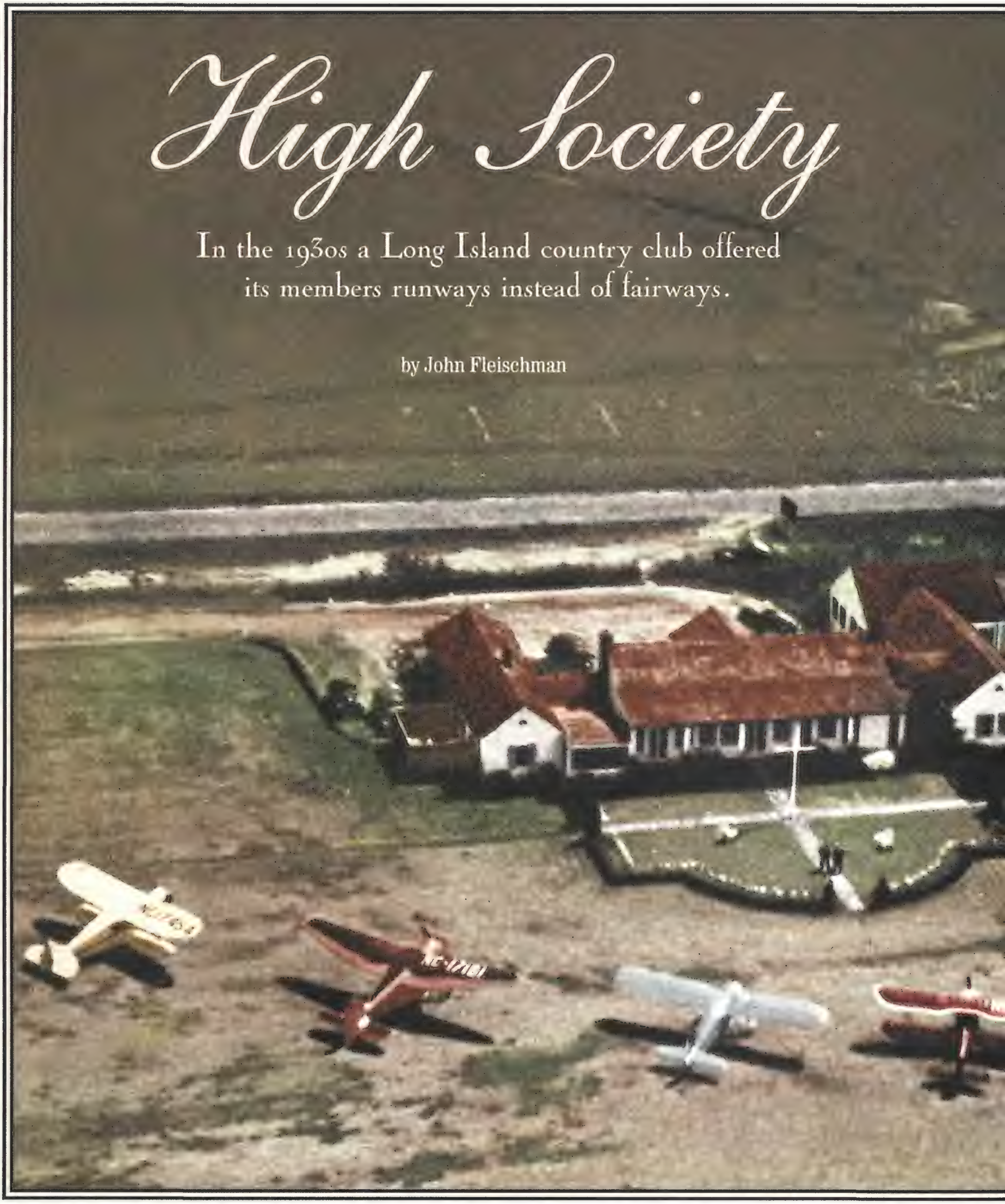
Although known for its big gun, the A-10 can carry laser-guided, cluster, and air-to-air munitions.

controller (FAC) releases a parachute flare to create an artificial moon. Standard flares dropped to help an aircraft evade a heat-seeking missile can also be used, but they burn for only about a minute. Either method alerts the enemy, but two solutions in development offer almost-total stealth. In the near future, A-10 pilots will be able to drop parachute flares that emit light in the non-visual spectrum, but that can be seen by a pilot wearing NVGs. Another development is a rocket flare, already in use by the Army, that also emits non-visual light. Gulf War veteran Major Joe Nuti welcomes the improvements that have gone into the Warthog for daytime operations but is even more impressed with the improvements that NVGs offer. "We're probably three to five times better during the daytime, but at night I can't even put a number on it—a hundred times better, maybe," he says. "The NVGs just turn night into day."

When A-10 pilots fly as FACs, they will soon be using their NVGs in conjunction with an infrared laser, an Air Commander's Pointer, which the pilot attaches to his finger with Velcro. While patrolling for targets, often in communication with ground forces, an A-10 FAC will simply point his finger at a truck, tank, troop concentration, or artillery piece, and fellow NVG-wearing pilots will be able to see the laser dot on the target they are to attack. Under certain atmospheric conditions, they may see the beam itself. While using the pointer, pilots wear protective, wraparound laser-protective glasses under their NVGs to guard their eyes in case the beam reflects off the canopy as it leaves the aircraft. A primary advantage of this system is that teaming NVGs with the pointer allows covert target selection—not very long ago, FACs still relied on smoke rockets that revealed the intended target, as well as the FAC aircraft, to the enemy.

The new-found acceptance of the A-10 is perhaps best exemplified today by potential fighter pilots who, having performed well enough in training to qualify for any aircraft in the Air Force inventory, choose the Warthog. "When I was going through the T-38 phase of my training, it seemed like the instructors who had flown the A-10 really enjoyed the thrill of flying, and when I talked with them, they spoke of their days flying the A-10 as a role they really loved," says First Lieutenant Diane Ridgely. "They didn't have any problem with the image—they weren't concerned about that. But they loved that kind of flying. That was what turned me on to the A-10. . . . Just to step up to a jet and have it be the ugliest thing out there and know that everyone's watching it as it takes off—that makes it all worth it."

The upgrades are still coming. A-10s are getting global positioning system equipment that will work in conjunction with a new and more accurate inertial navigation system—thus providing a highly reliable way to keep pilots on track. Warthogs will also receive a digital data-sharing cartridge system, like that on the F-15 Eagle and F-16 Fighting Falcon, that will allow mission planning to be done on a computer and the data, including waypoints and target information, to be simply plugged into the A-10 before a flight. The LASTE software promises open-ended growth, and until the Joint Strike Fighter is fielded—in at least a decade—the A-10 appears to have a secure future, and its supporters, vindication.

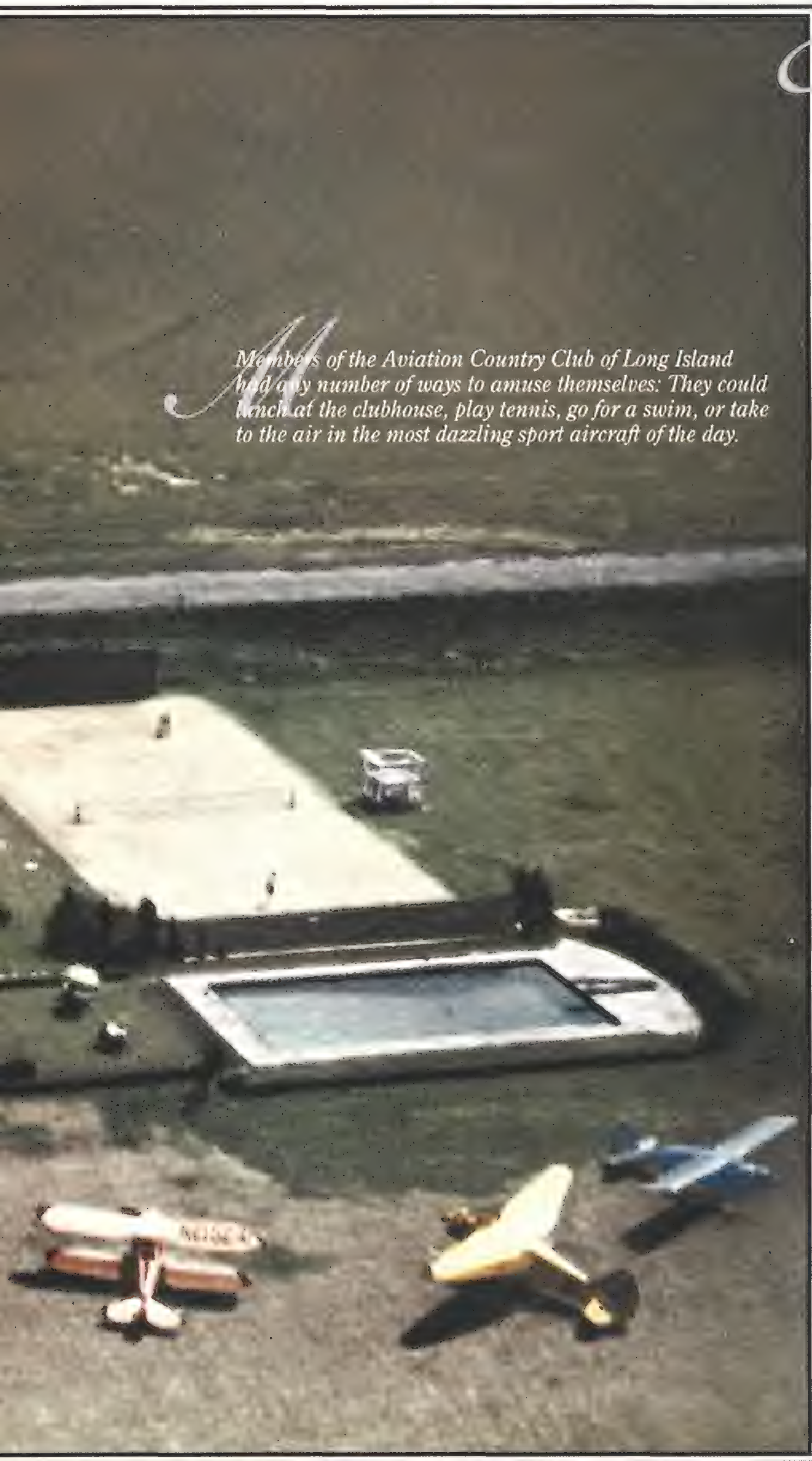


CRADLE OF AVIATION MUSEUM, GARDEN CITY, NY

High Society

In the 1930s a Long Island country club offered its members runways instead of fairways.

by John Fleischman



Members of the Aviation Country Club of Long Island had any number of ways to amuse themselves: They could lunch at the clubhouse, play tennis, go for a swim, or take to the air in the most dazzling sport aircraft of the day.

ALL PHOTOGRAPHS DIGITALLY ENHANCED BY RANDY MAYS

He was 11 the year his family moved from the Eastern Shore of Maryland to the farmland of Long Island, and what Alfred Merrill remembers from the first day was the sky. It was alive with airplanes. In 1936, Merrill's new home, Hicksville, New York, was both in the middle of nowhere and at the forefront of aviation. Farming was still king on Long Island—potatoes and ducks—but flying was coming on strong, even during the Depression. In the skies over his new house, Al Merrill could see it all.

Not five miles away was Roosevelt Field, the busiest civilian airport in the country and the field where Charles Lindbergh's fuel-heavy *Spirit of St. Louis* had staggered into the air, bound for Paris in 1927. Next door to Roosevelt was the U.S. Army's Mitchel Field, the site in 1929 for Lieutenant James H. Doolittle's first "blind" takeoff and landing using experimental devices developed on the Island by Elmer Sperry's instrument company. Sperry was one of a group of businessmen and engineers transforming the aviation business and, in the process, Long Island. For manufacturers like Leroy Grumman and Sherman Fairchild and designers like Charles Lawrance and Grover Loening, the air over Long Island was their testing ground.

Long Island had one other thing, even during the Depression—wealth. The North Shore towns of Port Washington, Glen Cove, Huntington, and Oyster Bay were the capitals of the Island's Gold Coast. Here New York's old money and newest fortunes coexisted, at times uneasily, in a world of mansions, beach cabanas, racing sloops, roadsters, tennis courts, lawn parties, and, by the 1930s, private aircraft.

Merrill remembers the first day he stepped out of his house to watch a small airplane, propeller roaring and wings glinting, rise from the potato fields just across the road. There was a private airfield right at his doorstep (a very private airfield, Merrill learned), the Aviation Country Club of Long Island, a unique and now largely forgotten institution in American flying history. Between 1929 and 1948, the club was where high tech met high society.

Merrill went to work there when he was 16, thanks to the war. Tormented

NASM (2)

The club's roster included such notables as airplane designer Alexander de Seversky (at right) and Jacqueline Cochran, who flew this Seversky aircraft to victory in the women's division of the 1938 Bendix race sponsored by Vincent Bendix (left). Amelia Earhart (below) also belonged to the club, but it was her fame, not her lineage, that got her in.

in 1942 by visions of German paratroopers descending on unprotected airfields, Washington ordered all private coastal fields manned 24 hours a day or closed. The manager of the Aviation Country Club of Long Island called the principal of Hicksville High School, Miss Farley, to see if she knew anyone who might be interested in coming after school to help the mechanics, who were on duty till five, then babysit the telephone until the night watchman (or German paratroopers) arrived at nine.

Merrill seemed the natural candidate to Miss Farley. The job was six hours a day, six days a week, and paid the princely sum of $15. Merrill snapped at the chance. "I think if they would have asked me to pay them to work I believe I would have done it because I wanted to be around airplanes so bad," he says. As a club hangar employee, Merrill was required to wear a pair of white coveralls embroidered with the club's blue and gold logo. "I felt real proud walking around in those coveralls," he remembers.

Being around that many airplanes was intoxicating. Merrill happily spent afternoons fueling and starting the members' dazzling assortment of sport aircraft—Wacos, Grummans, Stinsons, Beechcraft, Aeroncas, Fairchilds, Taylorcraft, Ercoupes, Stearmans, and others. The club insisted that each night all aircraft be stored inside a double-wide hangar, so come evening Merrill jockeyed them back inside. "At nighttime when nobody was around and I didn't have any homework," says Merrill, "I could go out there and sit in an airplane and try to memorize the instrument panel and things like that."

A few club members were "horses' asses," Merrill recalls, snooty and rude to ground crew. But Merrill knew his place. "I mean, the kind of people, clientele, they had out there were the rich and the famous, and you were polite to those kind of people," he says. "If you weren't, you didn't keep your job very long." Some of the members, however, went out of their way to be sociable. Merrill remembers Roy Grumman returning to the club airfield after shooting sea landings in his amphibious Grumman Widgeon. As a hangar employee, it was Merrill's job to hose the seawater off the Widgeon. Merrill's employer was charging what he thought was big money—$5 a pop—but here was this wealthy guy apologizing to a high school kid for the extra work he was causing.

Another favorite was Roger Wolfe Kahn, who was the very picture of the well-heeled, well-dressed sportsman pilot. "He had a Fairchild 24 out there and Roger would come out, and he had on these fancy tweed suits and these shirts that he must have paid $15 or $20 for," says Merrill. "This was 1942 and that was more than I made in a week. He'd maybe fly around for about a half-hour. He'd come back down and he'd come back in the shop where we were working on something. He'd take his jacket off and hang it on the drill press arm. He'd get his hands right into what we were working on. And I've seen him get his shirt just filthy dirty. I think he had more fun associating with us in the shop than he had flying his airplane."

Because of a wartime labor shortage, Merrill was often a one-man ground crew. Members would call ahead so he could get their airplanes gassed up and check the oil. The club's office would sound the Klaxon horn when the member arrived, and Merrill would push the aircraft out to the flightline. Small planes rarely carried their own battery starters in those days, so Merrill would stand by to pull the prop.

One day a very tall, very thin, very withdrawn-looking man came out to fly the Club's Stinson 105. (The Club's rental rate in 1942 was $17.50 an hour.) Merrill greeted the pilot and held the cockpit door while he climbed in. "I said the

usual stuff: 'Switch on. Gas on. Brakes on,' " says Merrill. "I went ahead and pulled the prop through a few times and I said 'Contact' and pulled it through one more time and it started and I waved him onto the ramp and he took off and flew. And then I went back in the hangar and I think Irene Muller, they called her 'Mama' (that was her nickname), I think Mama stuck her head out of the door and said, 'You know who that was?' I said, 'I don't know. Never saw him before in my life.' She said, 'That was Charles Lindbergh.' I said, 'You're kidding me.' She said, 'Come here. I'll show you.' And they had a flight sheet that you had to sign before you took an airplane off, and lo and behold, I looked down there and there was his signature on that thing and I said, 'Well, I'll be doggone.' "

Lindbergh was a charter member of the club in 1929. He was brought in by its first president, Charles Lanier Lawrance, who'd designed the Wright J5C Whirlwind air-cooled radial engine for the *Spirit of St. Louis*. Lindbergh, who had just married Anne Morrow that May, taught his bride to fly at the club. The club's treasurer was another giant of the aeronautics industry, Chance Vought, and the board was fleshed out with society types, such as Cornelius Vanderbilt Whitney and Reginald Langhorne "Peter" Brooks, a band leader and a superb young pilot (he was also the nephew of Lady Astor).

On Long Island, this elite group formed what they thought would be the first of a string of aviation country clubs that would extend from coast to coast. A national committee had been formed in April 1928 to issue charters, and at one point, 114 such clubs were supposedly in the works. Fliers Ruth Nichols and Robert Oertel were dispatched to scout suitable sites by air. Eventually it came down to 25 promising locations, including Boston, Philadelphia, Pittsburgh, Cleveland, Chicago, Detroit, Cincinnati, Memphis, and Tulsa.

The Aviation Country Club of Long Island opened in June 1929, and the stock market crashed four months later. But despite the downturn, at least two other clubs were built, one just across Long Island Sound in New York's Westchester County and one in Los Angeles, which counted among its members several of the day's movie stars. For such swashbuckling actors as Douglas Fairbanks, Reginald Denny, and Wallace Beery, flying your own airplane was a masterful public relations move. The Los Angeles club also had high-flying society types such as "Marjorie Crawford of Los Angeles and Santa Barbara," who, it was reported in July 1929, "alternates between flying and swinging the polo mallet."

This breathless report comes from the pages of the *Sportsman Pilot*, which wrote in 1929: "The Long Island club is no longer a test tube. It may have been an experimental device at first. Now it has been elevated from the laboratory. It has become a beacon for guidance of other club units.... The Hicksville club has not contented itself with fair-weather flying and tea at the clubhouse, skeptical suspicions to the contrary notwithstanding."

For all the snobbish overtones, the Long Island club was set up for serious flying. A huge hangar was built, 200 feet wide by 60 feet deep. Until the Second World War, two mechanics were on duty every day with four helpers to gas up the airplanes with high-octane fuel, push them onto the line, and hand-prop the engines. And in nearly 20 years of flight operations, the club never had a serious accident resulting in injury—not even at the annual airshow. Instead of death-defying stunts and hell-for-leather pylon races, manufacturers used the show to put on dignified exhibitions of their latest products. The Flying Committee's 1939 invitation to manufacturers made the tone of the event clear. "Each demonstrator will be asked to demonstrate his ship in the air for approximately five or six minutes. The Committee will permit no stunting, excessive pull-offs and climbs or unorthodox maneuvering, the demonstration being purely to show off the ship's best qualities.... It is important that each demonstrator realize that he is not in competition and also that no sales approaches be made."

The chance to present the best aircraft to the best people was irresistible to those in the business (many of whom belonged to the club anyway), and the shows were hugely successful—too successful in some ways. Club mem-

CRADLE OF AVIATION MUSEUM, GARDEN CITY, NY

The club held an annual airshow, at which well-heeled guests could watch the goings-on from the clubhouse veranda.

bers and demonstrators were issued entry ribbons, but keeping the ordinary people of Hicksville away was difficult. They lined the roads and trespassed on the airfield for a glimpse of the amazing craft on display or flying by. In 1939, the club had TWA's "stratosphere laboratory plane" and a trio of Goodyear blimps, as well as flybys from Pan Am's Sikorsky S-42 *Bermuda Clipper* flying boat and the Douglas DC-4 prototype. The crowds, both beribboned and uninvited, were enthralled.

From the beginning in 1929, the club was a perfect place to fly, recalled former member Betty Gillies, who died last October at the age of 90. It had 100 acres, most of it an "all directions" grass landing field in the midst of an endless plain of potatoes. In case of a forced landing, the potato fields were a great reassurance, said Gillies. Her family still has a scrapbook of those early days, and they allowed a look at photocopies of her early Hicksville snapshots. Here is a black-and-white photograph of her first ship, a de Havilland 60 X Moth, on the club field. She bought it from Grover Loening, who had the airplane shipped from Britain. His aeronautical engineering firm put it on floats, and Bud Gillies, Betty's husband, was Loening's test pilot. When Loening was done, Loening sold the Moth to Betty. She put it back on wheels. "We were in the business," Gillies explained matter-of-factly, "so we had the airplanes."

And here's a picture of the club's president, Charlie Lawrance, on the clubhouse terrace. Wrought iron lawn chairs have been dragged out into the sun. There's Bud, Betty's husband, seated on Charlie's right. On Charlie's left is Amelia Earhart, wearing a tailored dress and a cloche hat. The elegant woman next to her is British pilot Lady Heath, who in 1928 explored Africa by air.

CRADLE OF AVIATION MUSEUM, GARDEN CITY, NY

Situated on a 100-acre site, the club's grass airfield was surrounded by potato farms, which doubled as emergency landing fields.

Fame, money, and high-flying connections: These were the requirements for membership. The Aviation Country Club was not for everyone. "There was a board that directed it, and, yes, you did have to be socially acceptable and [able to] afford to join the club and afford to fly," recalled Gillies.

Just how exclusive membership was can be gauged in a series of letters written by aviation entrepreneur Sherman Fairchild. The correspondence, now archived at the Library of Congress, shows Fairchild's attempts to engineer a membership for friend and business associate Duncan B. Cox. To get a second letter of recommendation for Cox's application, Fairchild wrote to the club vice president, Luis de Florez, an engineer who was pioneering the development of aviation fuels and lubricants. A week later, Fairchild had a "Dear Sherman" note back from de Florez. All was not well. "I frankly know very little about him other than he has been associated with you in a business way," wrote de Florez. "I should like to know something about his background, education, clubs, etc., which doubtless you know about." De Florez also suggested that Cox stop using his guest privileges at the club while his name was under consideration. "There is a feeling among a number of members of the Club that membership has been taken lightly and that there is a tendency to consider it a mere convenience," added de Florez.

Fairchild hurried back with an amplification, outlining Cox's education at a noted Connecticut prep school and at Yale, where he was on "the Varsity Football Team for two years and on some All-American teams." Fairchild mentioned Cox's father, a vice president of a major corporation, the lineage, education, and society track record of Cox's wife, and the names of Cox's best friends on Long Island. Fairchild wrapped up with his friend's 12 years as a licensed flier, his association with two other aviation companies besides Fairchild Engine and Aircraft, and two of Cox's clubs, which included the Island Court Tennis Club. Fairchild assured de Florez, "I have the same outlook on the Club as you have and am most anxious not to have it become a little Roosevelt Field. The character of the Club as a social association is the real reason for its existence."

It was not enough. Whether Fairchild's assurances came too late or whether Cox had committed some unspeakable *faux pas* as a guest, the board of governors forwarded to Fairchild "as a courtesy" a copy of their letter to Cox frostily informing him that they were unable to recommend him for membership, supposedly because his application was incomplete. Club Secretary R.R. Loening continued, "I am instructed to advise you, also, that the maximum guest privileges extendible to you, under the rule of the Club, having expired, it will

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club newsletter noted in August 1938 that "Mr. Roy Grumman is now keeping his new G-32A in the hangar. It is a two-place conversion of the Navy F-3-F fighter with an 830 HP Cyclone. It can climb to 12,500 feet in five minutes." Imagine a modern day "Mr. Grumman" rolling up at a general aviation field in a civilian version of his company's Navy F-14 Tomcat. The same issue noted that Mr. Howard Hughes had dropped by the club at the conclusion of his record three-and-a-half-day around-the-world flight and had been ferried back to Newark Airport in the club's Stinson.

Look at some of the people in and around the club—pilots like Lindbergh, manufacturers like Grumman, and behind-the-scenes men like de Florez. Did they ever find themselves around the same table at the clubhouse in those critical years leading up to the bombing of Pearl Harbor and the United States' entry into World War II? That's probably the most frustrating thing about studying the Aviation Country Club of Long Island, says Joshua Stoff, curator of Nassau County's Cradle of Aviation Museum. The club was "bringing together a lot of important aviation people—manufacturers, engineers, and pilots—together to talk," says Stoff. "But we don't know what was said over dinner. The impact that it had would not have been [known]."

not be possible to continue your residence at the Club."

Those who were selected as members in the club had to be more than fliers, says Nancy Graham, who was a flight instructor there after the war. She got her job in the summer of 1947 through a flying and social acquaintance. "Well, I was brought up with these people," she explains from her home in Charlottesville, Virginia. "I've had a very fortunate life. A man called Steve McClellan, who was a member, telephoned me during the summer—I was down in Charlottesville with my mother—and said, 'Would you like to come and be our instructor at the club?' *Well*, I thought, *That sounds nice*. So I started as soon as we moved back to my mother's Glen Cove property."

Graham remembers that the club's social circle included people like William Woodward of Oyster Bay, whose family owned a horse-racing stable. One night, Graham recalls, Woodward and his wife threw a dinner party for the Duke and Duchess of Windsor (as part of the younger generation, Graham had been invited to come after dinner). Club members who were not acquainted with royalty or who were not so well heeled had to have other qualities to recommend them. "[If] you were a top pilot," says Graham. "That's how Earhart would have got in. Those things are always possible. You become famous, you're welcome."

The club's mix of status, wealth, and insider connections produced some unusual scenes on the flightline. The

Airplanes designed by Seversky (above), though sleek and fast, were not as prevalent at the club as those manufactured by fellow member Walter Beech (below, right), whose sturdy biplanes were sometimes flown by the club's most famous member, Charles Lindbergh.

The war seemed to help the club in the first months; flying lessons were in high demand. Barbara Kibbee Jayne was hired by Bud Gillies early in 1942 as the club's chief instructor. He'd flown up to Troy, New York, where Jayne had just qualified as the first woman instructor in the new Civilian Pilot Training Program, just to talk her into it. After she reported for work in Hicksville, there weren't enough hours in the day. She taught seven days a week, dawn to dusk. "All kinds of people went out and learned to fly," she says. "To this day, I can't think of anything more thrilling than a first solo. It was just you and God." Besides the Almighty, the club membership also took an interest. Jayne remembers folks rushing out of the clubhouse and lining up along the terrace overlooking the runway, where they made bets on how many bounces the returning soloist would make on landing.

Despite the workload, teaching flying at the club was fun for Jayne in ways that it never was after the war. In 1942 aviation fuel was not yet being rationed, and members could still fly up to Nova Scotia to pick up salmon or down to the Chesapeake Bay to hunt ducks. Some club members joined the Civil Air Patrol and were sent out to monitor the coast, where they "spotted quite a few submarines off the island," Jayne recalls.

Still, there were members, or at least their wives, who came to the club purely to socialize. And the club obliged them with an endless round

of tennis tournaments, dances, and swimming parties. "It was not the kind of place where people went out on Sunday and stood around and watched the airplanes," recalled Betty Gillies. "It wasn't stuffy at all but it just didn't serve the same purpose that a commercial airport does. There was a swimming pool and a tennis court in addition to the airport so that there were other activities and people could give parties of their own there, you know." One night all of the airplanes were pulled out of the hangar so that members could hold a roller skating party inside.

Gillies' photo collection shows a slightly more sedate gathering: a tea party. Bud Gillies, Charlie Lawrance, Amelia Earhart, and Lady Heath have tea service before them on a little table, and a waitress has just arrived with a shiny metal pot. Relaxed, wearing expensively casual clothes, they could be at any high-class watering hole of the period except that behind the seated figures, across the neatly trimmed grass, is a row of biplanes—wonderful biplanes. Shiny and sleek, they display the awkward grace of between-the-wars sportplanes, a style that's bound up in wires, struts, and open cockpits.

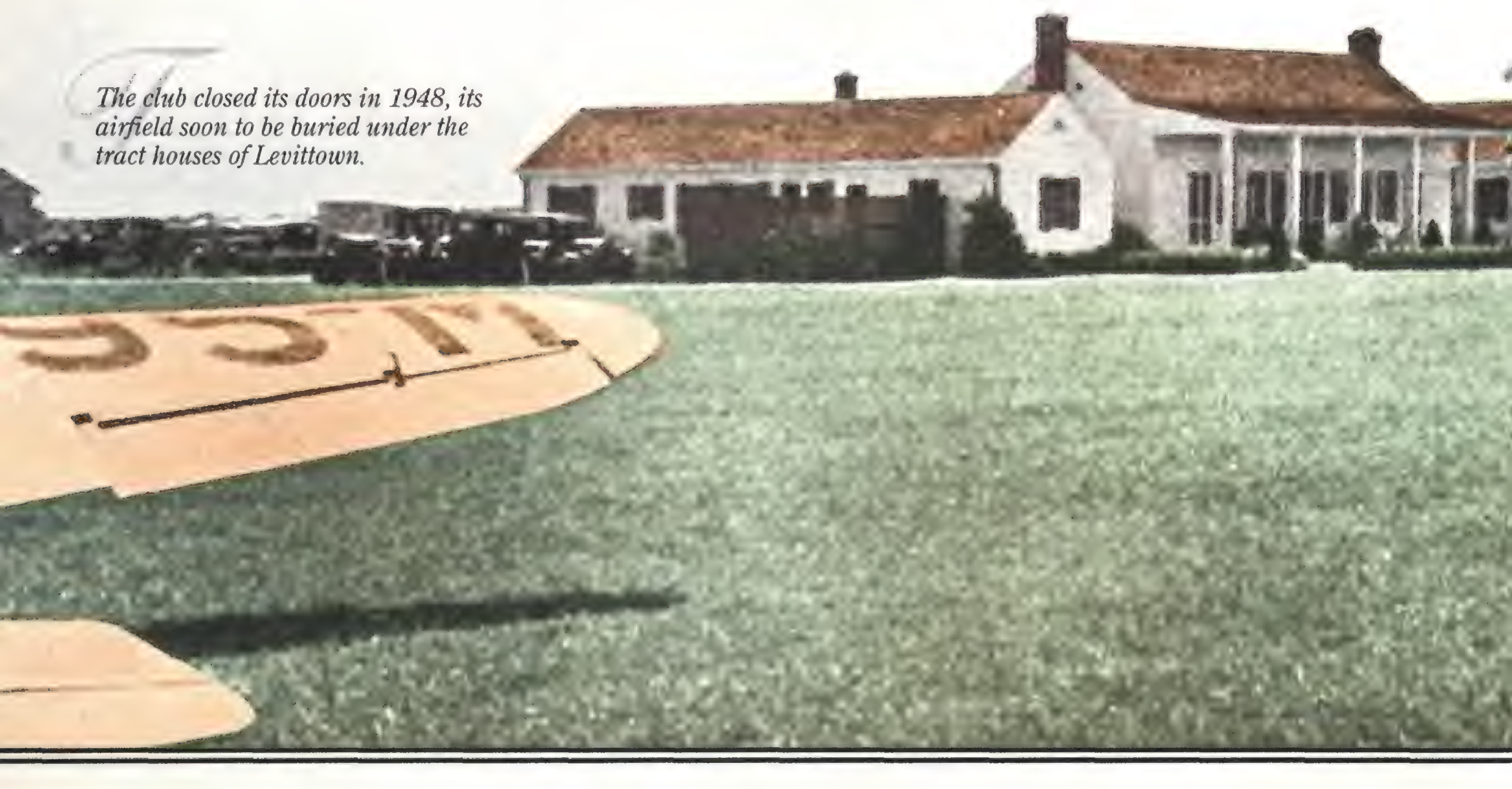
Over time, the fabric-covered biplanes were joined by high-wing monoplanes such as the Fairchild Ranger, and then the first all-metal sport aircraft, such as the Ryan S-T. These and other models are the signature airplanes of what historians now call the Golden Age of Aviation. Other aircraft based at or visiting the club included the Beech 17, Bellanca Skyrocket, Lockheed 10, Boeing 247-D, and Grumman G-21.

The club had some brilliant pilots to fly those airplanes, Jayne recalls, women like Betty Gillies, who was her good friend, and Miriam Crocker, an heiress who owned a beautiful Waco-D that she flew within an inch of her life. And then there was Peter Brooks. "Ah, Brooks," says Jayne, remembering him stunting above the potato fields and under the power lines. "Brooks used to take his biplane way off on the west side [of the field] and get it upside down and then bring it in under the wires," she says.

But as the war continued, the club found it harder and harder to retain good help. Even Alfred Merrill, the teenage airplane jockey, had gone off to war, as an instructor for B-29 flight engineers. Jayne says Grumman would lend mechanics to the club for a day or an afternoon. They were wonderful technicians but given to practical jokes, she says, particularly catching mice (of which the hangar had an inexhaustible supply) and hiding them in the drawer of Irene "Mama" Muller's desk. "You could hear her scream across the field," laughs Jayne. Eventually Jayne was forced to press Irene into service on the flightline. "Irene didn't know how to drive a car," she says, "and we had this big Texaco gas truck [for the aircraft]. So I taught her to drive on that."

By then, the club's wartime flying days were numbered. Jayne herself was spending more and more time test flying production aircraft at Grumman. Many of the club's women members had gone into the service as ferry pilots. Jayne is not sure exactly when the club suspended operations for the duration of the war, but almost her last memory of the club was of a party there—not a high-society event but a wedding thrown by the Polish refugee couple who served as the live-in housekeeper and cook. "They were just wonderful, wonderful people," she recalls. "And they got permission from the committee to hold this wedding in the kitchen, and they asked most of us from the hangar to come to the dance. They hopped up and down for three nights. I'd never seen dancing like that."

To be sure, the Aviation Country Club of Long Island survived the war and resumed operations. Merrill, however,



The club closed its doors in 1948, its airfield soon to be buried under the tract houses of Levittown.

did not get back to Long Island to visit his parents until the spring of 1948, only to be told the club had just closed permanently. Standing outside his parents' house in Hicksville, he found the silence strange. There were no small aircraft taking off from the club airfield. On another visit, Merrill drove over to see for himself. "The place had been bulldozed and they were building Levittown," he recalls. "The buildings were gone. What happened to all our planes I can't say, but everything was gone."

For some, that's the final irony of the Aviation Country Club of Long Island: It's buried under Levittown. What was once an elite social club in pre-war America was sold off for post-war America's most famous mass-housing development. For former members like Betty Gillies, the memory of the club's end was painful. "That horrible time," she said. "Those little houses. Hundreds of them."

The club had fallen victim to rising land values. While Hicksville was charmingly rural in 1929, twenty years later it was about to become solidly suburban. And as the houses closed in, it became dangerous to operate an airfield. When William Levitt offered $2,200 an acre, the club ceased flying in May 1948 and began looking for a new home. The hangar was sold and reassembled in nearby Bethpage, where it served for years as a perfume factory, then a pickle works, and finally a tuxedo warehouse. Local historians say parts of other club buildings were trucked away and incorporated into five private homes.

The club planning committee found a new site in 1950, a small private airport at Commack. The committee reported that it was only "fifteen minutes further away from New York City (by car) than our present location...being readily adjacent to the new Northern State Parkway Extension." The committee added that the 100-acre field could be acquired at $550 an acre, and so with only 50 members paying $3,200 a year, the club could take to the air again. The members, however, had lost interest. That August, 90 percent voted to dissolve the club forever.

Museum curator Joshua Stoff says that after the war, aviation on Long Island steadily declined. Much closer to Manhattan, LaGuardia Airport opened in 1939 and Idlewild (later renamed Kennedy International Airport) in 1948. Roosevelt Field closed in 1951 and Mitchel Field shortly thereafter. Both were torn down for shopping centers.

Today a street in Hicksville called Pilots Lane is virtually the only sign that the Aviation Country Club of Long Island ever existed, but the club lives on in snapshots and memories. Al Merrill remembers Barbara Kibbee Jayne's friend, Miriam Crocker, as the "old lady" in a hot airplane, a Waco-D with a compressed-air starter. "I mean, she looked old to me but as a teenager maybe my judgment of age wasn't good," he says. "But she had that airplane completely redone and the wings were cream and the fuselage was brilliant firetruck red."

Merrill would push her Waco out to the flightline, prime the engine by pulling the propeller through a couple of times, then step back. "She'd hit that air start and that thing would go—*chugga chugga chugga*—the weirdest damn thing. And then all of a sudden she'd turn the ignition on," he says. "That thing, it always fired. She'd take that rascal and she'd go out there and about mid-field, she'd haul back on the stick, and I mean to tell you it was like she was trying to go straight up. It'd scare the daylights out of everyone.... I never did see a single person watch her take off who didn't just watch her until she almost got out of sight because they were sure she's going to stall."

But she didn't stall. Off she went into the sky. "Never saw anything like it," says Al Merrill. We never will.

CRADLE OF AVIATION MUSEUM, GARDEN CITY, NY

TALK RADIO

How groundlings and space travelers shoot the breeze.

by Greg Freiherr

Illustrations by Richard Thompson

Dave Larsen had used his ham radio for talking to friends in faraway places for years when one night he and a buddy decided to reach a little farther. They had heard that by tuning to a frequency of 145 megahertz with a few hundred dollars' worth of equipment—transmitter, receiver, antenna—they could contact the space shuttle. But what they heard over the airwaves that evening in 1991 was a voice speaking in Russian.

Larsen thought it was just somebody on the ground fooling around, but his friend told him it was a transmission from a Russian satellite. Still not believing the voice was coming from space, Larsen, who speaks serviceable Russian from training he received in the U.S. Navy, replied in Russian and was surprised at the response. "He [cosmonaut Musa Manarov] went about a thousand miles an hour," remembers Larsen. "I told him to slow down, and he goes, 'Next orbit.' So I go, 'Okay.' And we talked the next orbit, and I went, 'Holy mackerel!' "

Ham (no one is quite sure how the nickname originated), or amateur, radio equipment has been present aboard the Russian space station Mir since 1988, and since 1983, amateur radio equipment has flown on more than 30 space shuttle missions. Over the years, there have been thousands of contacts between ground and orbit, ranging from brief exchanges to real conversations.

After making his first contact with Mir, Larsen was hooked, and it wasn't long before he developed a radio friendship with another cosmonaut, Alexandr Kaleri. Both men had served in Vietnam: Kaleri was a Soviet advisor and Larsen was a helicopter gunship pilot whose mission was to hunt down men like Kaleri. "We talked about it and he more or less said, 'That was then, this is now, and we are all one now,' " Larsen recalls. "When he made that statement, I felt we had better things to talk about."

The two have had dozens of radio conversations, as well as a prodigious

written correspondence. Mir has an onboard message system that allows the exchange of small text files, and Larsen and Kaleri used to send e-mail several times a day, with Larsen often helping to satisfy Kaleri's hunger for information about the history of the U.S. space program.

Craig Stewart, a radio operator in Petoskey, Michigan (call sign kb8kpv), has had dozens of contacts with astronauts and cosmonauts, enough so that he has been able to pick up on the personalities of those in orbit. Of NASA astronaut Jerry Linenger, who spent four months aboard Mir, he says: "Jerry was kind of nice. He'd like to talk to you. He'd actually have a conversation with you. Now, Norm Thagard [the first NASA astronaut stationed aboard Mir] was just the opposite. He really liked just making quick contact with people. He'd say 'Hi. How ya doin'? I gotcha. I hear ya loud and clear.' And then he'd move on to the next guy."

That's the rub, though part of the challenge, with amateur radio: There's always a next guy. In fact, there are dozens of next guys. Mir, for example, orbits Earth every 92 minutes, and at any given point during an orbit, the radio equipment aboard the station has a footprint, or area, roughly 75 percent of the continental United States, from which it can detect radio signals. When Mir passes over the United States, an operator like Craig Stewart has about a 10-minute window in which he can make contact.

Unfortunately for Stewart, amateur radio operators all over the country are also within Mir's footprint. So as the space station passes overhead, whoever is manning the onboard radio is greeted with hundreds of voices simultaneously yelling out their call signs. The cosmonaut or astronaut on board will then pick out the strongest signal and repeat the call sign back to the sender—an invitation to begin an exchange. The radio operators who didn't get picked can still listen in, but etiquette dictates that they wait until a conversation is finished before they again start trumpeting their call signs. Often, though, this is not the case. NASA astronaut Michael Foale, who spent four months aboard Mir, remembers the "huge voice congestion" over the United States and Europe. "No one is willing to listen to you finish your conversation and not transmit," he says. "They break in. It drowns out the signal. You cannot maintain a conversation with anybody. You can barely exchange the call sign."

Foale tried to circumvent the congestion by tuning to the 70-centimeter signal, the less popular of the two FM bands that amateur radio operators can use to communicate with Mir and the space shuttle. Most hams, however, prefer to broadcast over the two-meter-wavelength band because this longer wavelength is not as susceptible to Doppler shifting, which occurs as the spacecraft approaches and then recedes. Some radio operators like to work the dials, tuning the frequency by hand as Mir moves across the sky. Others use electronics to handle the shift.

Of course, ham operators with the most powerful equipment (what Stewart calls the "big guns") have the best chance of getting through. The output of amateur stations ranges from 25 to 100 watts—about as much energy as the lightbulb in a living room lamp. For the best and most consistent results, however, hobbyists should have at least a 45-watt radio and a simple single-wire antenna, which sends out a doughnut-shaped signal. Reception improves markedly with a computer-controlled tracking station that can automatically direct the antenna, pointing it right at the spacecraft as it moves quickly across the sky.

Ingenuity and persistence, though, can sometimes outfox the big guns. Take Troy Fehring, a farmer of alfalfa, wheat, and cattle in the tiny town of Sterling, Oklahoma. Fehring, who has been an amateur radio operator for 10 years (call sign n5vin), likes to listen for the space shuttle and Mir while he's plowing fields on his John Deere tractor. On October 28, 1993, he got lucky. It was around noon, and because Fehring knew that the shuttle would be passing overhead, he stopped the tractor ("Man, I hit the brakes and kicked it out of gear," he says). Mounted on the top of the tractor's cab was a two-meter simplex FM radio. "That little radio did 25 watts," says Fehring. "All I had was a five-eighths-wave, omni-directional, mobile antenna. And it's hard to go against those guys that are sitting there with computer-tracking antennas. But I heard [the shuttle] and I just took a chance. I said, 'This is n5vin John Deere mobile.' And [mission specialist William McCarthur] came back, 'n5vin John Deere mobile' and said, '73' [ham speak for "best regards"] and then they go to the next guy. You call them all the time, and when they finally come back to you, it's like, wow!"

The American Amateur Radio Relay League confirms that Fehring's exchange was the first farm-tractor-to-space-shuttle communication. Fehring received plenty of local media coverage, and even five years after his triumph, people haven't forgotten. Says Fehring: "Everytime I see someone around town, they say, 'Have you talked to the space shuttle today?' "

While Fehring was tickled with just his brief exchange of call signs, some

radio operators want more. Friendly overtures, however, don't always translate through the communications ether. Stewart, who used to program an alarm to sound whenever Mir came over the horizon ("As soon as I heard that thing, I'd run down in the middle of the night and try to make contact"), closely monitored Shannon Lucid's six-month stay aboard Mir. Stewart and Lucid had had several cordial but business-like exchanges when Stewart decided to try a little humor. A friend of Stewart's who works for NASA told Stewart that NASA had secured comfortable footwear (bowling shoe-style flats) for Lucid to wear immediately after her return from weightlessness to Earth's gravity. The friend asked Stewart to mention the shoes to Lucid the next time he talked with her.

"It was kind of an inside joke," recalls Stewart, but the humor wasn't apparent to Lucid. Here is a transcript of the exchange:

"[Friend at NASA] was up north, in northern Michigan, and he wanted me to mention to you that he had your bowling shoes and they look great," says an enthusiastic Stewart.

"Well, okay. Uh, that sounds good," says a bewildered Lucid.

"Well, he said you would know," says a suddenly nervous-sounding Stewart.

Lucid: "Okay. Why does he have them?"

Stewart: "Well, he doesn't have them directly, but he's seen them, and he says they look great."

Lucid: "Oh, okay, okay. Okay. Yeah, I just couldn't figure out why he had them up in Michigan."

Stewart: "No. He was up here visiting, and he wanted me to get a message to you via ham radio."

Lucid: "Oh. Okay. I understand. That sounds good."

At other times, ground-based radio operators end up striking an unintentionally funny note. Such was the case with Dave Larsen. "My Russian isn't the best in the whole world," admits Larsen. "Heck, it was three o'clock in the morning one time a [Mir] pass came over, and out of the blue, I made one big booboo in Russian. [The cosmonauts] died laughing probably for the next hour and a half—that's how long it takes to go around the Earth. And then they came back on and they go 'You know what you told us to do? You told us to go brush our teeth.' " (Larsen had been trying to inquire how often the cosmonauts bathed.)

Indiana-based amateur radio operator Mike Cox thinks he understands the appeal of ham radio for those in orbit. "These people are almost totally isolated from the rest of the world," he says. "It's like you and I can go out on the street any time we feel like it and walk up to a perfect stranger and say hello. The guy in the can up there, all he can

do is talk to the ground station at NASA or at the Russian space agency, and they can link him up with somebody, but you always know that the boss is listening. So the amateur radio opens up an avenue where they've got total control of it. And if they want to talk to somebody they can talk to them. If they want to talk to them about the baseball game, it's strictly their business."

Cox remembers talking to Norm Thagard at three o'clock in the morning. "He sounded absolutely bored to tears, and he sounded so glad to talk to somebody," says Cox. Though other radio callers could elicit only brief responses from Thagard, Cox had a different experience: "I talked to him for the whole pass. With Norm, you always gave him the latest Purdue scores."

Many astronauts and cosmonauts have welcomed the opportunity to chat. "If I had a free minute, I would turn on the radio and see who was there," says Ellen Baker, a veteran of three shuttle missions, two of which carried amateur radio equipment. "I was awake over Australia and New Zealand quite frequently, and I must have talked to hundreds of people in both those places. And there was one guy, either in Puerto Rico or Brazil, who was quite friendly. He was interested in getting to know me a little bit more than on the radio, but I think that was just the moment. I don't remember if he actually asked me out or not, but it was a little bit more than the usual chitchat."

Sometimes conversation isn't all that feasible, but Stewart discovered during Jerry Linenger's stay aboard Mir that the crew kept the radio on as an electronic companion of sorts. "I made a call up to him and he came back and I said, 'How are you doing?' He said, 'Boy, right now I'm in the middle of lunch.' And I said, 'Okay, I won't keep you.' " Stewart points out that Linenger could simply not have responded, but chose to do so when he heard someone radioing his call sign. Linenger says it was commander Valeri Korzun who turned out to be the real ham enthusiast. "He just absolutely loved ham radio," says Linenger. "While he was eating dinner, he'd be talking and trying his best to get some English out. So he'd be constantly asking me to translate what the person was saying to him. So I talked indirectly a lot on the ham as the translator—with food stuffed in my mouth and everything else, trying to help him out."

Astronaut Michael Foale, a ham radio operator before his visit to Mir, was one of the most outgoing NASA crew members assigned to the Russian space station. "Radio hams generally are more in love with the means of communication than communication," he says. "They would want to exchange a call sign with me and that's it, and then they would shut up. Whereas for me, on the

Mir, I'm much more interested in what people are doing on the Earth than exchanging a call sign. Collecting call signs is work. Talking to somebody about their lives is making personal contact. There was a guy in Canada who spoke to me regularly. He had a Pitts Special—that's a biplane. He'd go fly his biplane and do aerobatics in it and tell me all about it. He would make me envious talking about it, but it was nice to hear it. And there was a guy who runs some kind of PR business from his house way up in the north woods of Minnesota. Those are the contacts I remember and value because they had some meaning."

Probably one of the most meaningful Earth-to-space radio exchanges ever undertaken was initiated by Chris Edmondson (call sign vk3ce), a resident of Melbourne, Australia, who publishes *Radio and Communications*, an amateur radio magazine. Edmondson, who has been an amateur radio operator for 25 years, interviewed fellow Australian Andrew Thomas, the last NASA astronaut stationed aboard Mir. Over a week-long period in late April and early May of last year, Edmondson talked to and tape-recorded Thomas whenever he got the chance and published the entire transcript in his magazine. "The very first time I called him, he heard me and called back," says Edmondson. "I spoke to him orbit after orbit, for about 15 minutes per revolution." What Edmondson got was an insider's view of life aboard a space station.

Edmondson: "What about shaving? In the pictures I've seen you're clean-shaven. It would be awful to live in a fog of floating human hair. How do you keep things like that under control? Over."

Thomas: "Oh, it takes a bit of getting used to, I guess, but I shave by holding an electric razor in one hand and a vacuum cleaner in the other. It sounds silly but it works. Over."

The highlight of the conversation came when Edmondson asked Thomas about the view. "You can actually see from our orbit signs of human habitation," reported Thomas. "You can see, for example, a straight line scratched across the Nullarbor Plain which is, of course, the railway line. If the sun is at the right angle, you get shiny glints from the rails, as well as from rivers and dams."

In an accompanying editorial, Edmondson urged other amateur radio hobbyists to try their hand at contacting those in orbit. "Any radio amateur with a two-metre FM transceiver can work the cosmonauts aboard Mir or the astronauts on the U.S. space shuttles," wrote Edmondson. "Any of us. And anybody with no more than a hand-held scanner radio would be able to hear them too, as clear as a bell. Dial up 145.985 MHz and wait. Be patient."

Not all ham radio exchanges are as impromptu as the first one between Edmondson and Thomas. When NASA astronaut Dave Wolf was living on Mir, one of his childhood friends, Doug Rose—with the help of amateur radio hobbyist Cox—orchestrated a Hanukkah/Christmas call to Wolf from Cox's house in Westfield, Indiana, which is just north of Wolf's hometown of Indianapolis. Wolf's family and friends attended, but so did the local media. "The contact took place during the six o'clock news so it was kind of a zoo out in the street—these vans with these 50-foot masts up in the air," says Cox. "The neighbors thought I'd been caught for mass murder or something."

Rose had also arranged for the residents of metropolitan Indianapolis to turn on the lights of their homes and businesses during Mir's pass overhead. "When I was in the grocery today, strangers all came up to me and said they were going to turn their lights on," radioed Dottie Wolf to her son in orbit.

"I'm glad everybody's doing it," responded Dave Wolf. "I hope we don't blow anything out at the power station."

"The power and light company is thrilled with this," said Dottie.

And so was Doug Rose. "When you hear that unmistakable 'R-Zero-M-i-r coming over the horizon, over,' it sends chills up your spine," he says. "I got to talk to my buddy flying on a Russian spaceship. If that didn't blow my mind, nothing would."

As for Dave Wolf, he radioed to those on the ground: "I see the lights. It's incredible." Not a bad way for an astronaut to start the holiday season.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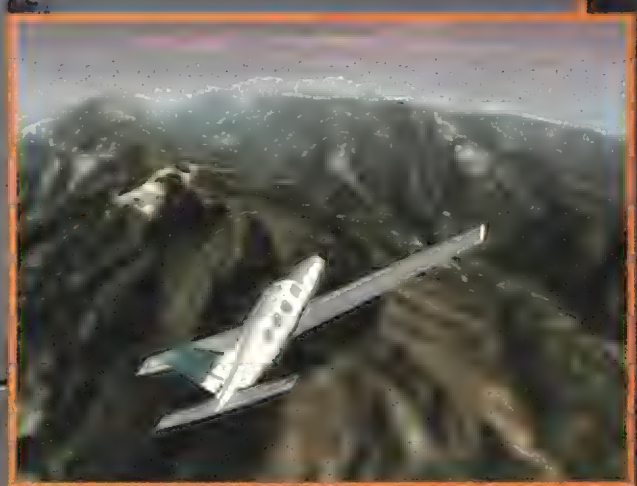

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On Your Mark, Get Set, BLOW!

by Joseph Bourque

The sky above La Baie Park in Gatineau, Quebec, looks like an enormous fishbowl, as 16 exotic airships glide at an altitude of 200 feet across the Ottawa River. They are the entrants in the Sixth World Hot-Air Airship Championship, and their pilots have traveled from Switzerland, France, Czechoslovakia, China, Portugal, Luxembourg, England, Belgium, Germany, Sweden, and the United States for this aerial Superbowl. The contrasting shapes, sizes, and colors, besides suggesting tropical fish, demonstrate that designers of thermal airships can take any number of approaches to get their craft to fly.

In the simplest terms, thermal airships are an imaginative cross-breed: Their envelopes are shaped like gas blimps but are inflated like balloons, with hot air instead of helium. The envelope provides the lift and incorporates a rudder for steering, while a piston engine, attached to an open passenger car suspended beneath the envelope, provides propulsion. The pilot uses propane burners to re-heat the air in the envelope during flight. The result is an airship that can navigate from point to point or meander where it chooses at a fraction of the cost of a gas blimp, while retaining the hands-on, out-there feeling of a hot-air balloon. For the championships, the airships will fly flat-out start-to-finish races over a prescribed course, hit targets with markers, make touch-and-go landings requiring the car to touch a target, snatch a marker out of the hand of an official stationed in a box, and even mimic slalom

JOSEPH BOURQUE

My sweet inflatable you: Thermal airships recline on the grounds of a Quebec park last September, gathering strength for the kickoff of the sixth World Hot-Air Airship championship.

races through gates. Most thermal-airship pilots are also balloonists. In the United States a hot-air balloon pilot license is the only requirement for flying thermal airships.

Don Cameron of Great Britain's Cameron Balloons is credited with inventing the thermal airship, which he debuted at England's annual hot-air balloon event, the Icicle Meet, in January 1973. "We inflated it in secret and then flew it to where everybody was getting ready to take off with their balloons," Cameron says. "No one had ever seen such a thing. A friend gave it a name at that moment—ISIBIDBI: I See It But I Don't Believe It." Cameron's one-time rival, Thunder Balloons, experimented with the concept and added pressurization to help retain the shape of the envelope. (Thunder later merged with Colt Balloons to form Thunder & Colt, which was acquired by Cameron in 1995.) Once a handful of airships were in operation, a competition naturally followed. The first world championship was held in 1988 in Luxembourg, where Sweden's Oscar Lindstrom, who is flying in this event, took first place. The championship is held every two years and has graced, in turn, the United Kingdom, France, Switzerland, and Italy. Canada hosted the sixth last September, the first to be held outside of Europe.

The array in this morning's Quebec skies, all of which are pressurized, includes a sprinkling of Cameron airships: the Czech Republic's *Nova*, England's *Shark*, and Switzerland's *AS Airship Ag*. Thunder airships are represented by Sweden's *Fujifilm* and the U.S. entry *Americana*.

The Chinese airship has attracted a lot of attention this year, simply because it's a non-European craft. The builder of its gondola, Beijing Keyuan Light Aircraft, also manufactures a small canard-and-winglet sport aircraft with a composite fuselage and a pusher propeller. *China-No1*'s gondola is simply that aircraft without the wings, fitted with a superstructure for attaching it to the bright red envelope, which is manufactured by a parachute company.

The new kid on the block is Lindstrand Balloons, formed by Per Lindstrand in 1995. Two Lindstrand airships are competing today, one borrowed from Lindstrand and a French hybrid with a Thunder & Colt gondola and a 300,000-cubic-foot Lindstrand envelope that makes it the world's largest thermal airship, the AS-300 *Rainbow*.

Even among this year's group of competitors, in which every craft is unique, one airship stands—or flies—apart. Smaller, brighter, and, well, odder than the commercially manufactured entrants, a handmade 56,000-cubic-foot airship putters in among the big fish. Brian Boland, a former high school art teacher who, with his wife Louise, owns a small airport in Vermont, designed, built, and is piloting the craft, which he calls *Dave*, loosely named after the David who took on Goliath.

Six months earlier, on a chilly February morning in Vermont, I watched *Dave*'s first flight. I arrived before dawn, and Boland, his wife, and two helpers were already well along. Boland was inflating a small hot-air balloon to use as a crane to lift the airship car from the second floor of his workshop and set it on the ground. "I use balloons for all

The airship entered by homebuilder extraordinaire Brian Boland stood out in a crowd of corporate gray suiters. Dave *was cobbled together for half the price of a commercial airship. Boland's motto: "Use what you have and make it work."*

sorts of things," he said. "I used one to lift the cupola that's on top of my house."

The fluorescent green and hot pink envelope (with red and purple accents) was laid out on the snow and the car was rolled into position for attachment. The material seemed quite flimsy. At 1.3 ounces to the square yard, the silicone-impregnated ripstop nylon is lighter than the material in most commercial airships, which can run to 2.5 ounces per yard. Boland's envelope weighs 140 pounds and fits in a bag the size of a beanbag chair. The construction is also different. "Most of the big guys use a catenary curtain [cables attached to a heavy fabric support and channeled to the gondola] that suspends most of the car's weight from the top of the envelope," Boland explains. "But my airship is so much lighter that I use load tapes sewn directly into the material. They distribute the weight around the circumference of the envelope."

Dave's gondola has six attachment points on its superstructure, which also holds the propane burners and the pressurization engine. Since the envelope has to be upright before the burners can be aimed into it without burning the fabric, it's pre-inflated with a gasoline-powered cold-air fan.

The pressurization engine wasn't running properly; it needed a different carburetor. And at the last moment, Boland discovered that one of his two 15-horsepower industrial chainsaw propulsion engines, which drive counter-rotating props, wouldn't start. He took off with only one engine running.

BRAD TRENT (5)

The envelope, please: Louise Boland logs hours at the sewing machine (below) to complete Dave, *which was designed, built, and test-piloted by her husband at their small Vermont airport (above).*

Boland and *Dave* glided around Post Mills airport at about 100 feet. As the equipage passed overhead, a spectator shouted "Look!" and pointed to the horizontal stabilizer, where a pair of scissors trapped in the fabric was silhouetted against the sun. "That's what happens when you work at 2 a.m.," said Louise. Later, instead of breaking a bottle of christening champagne over the airship's nose, we drank it.

Boland has since made several changes, the most important of which is a method for steering with his feet instead of pulling on ropes that control the rudder, as most airship pilots do. He's attached steering lines to the tips of a pair of cross-country skis on the front of the car and has run the lines through pulleys to the rudder.

As the last of the airships heads out over the Ottawa River on the second day of the competition, the leaders are already approaching the targets. I hear the occasional crackling of radios on the field as pilots report their whereabouts to ground crews. Through the staticky roar of her hand-held, Louise learns that her husband has been forced to land across the river with tangled steering lines. All the rest of the fish come back through the gate in good order, although one misses the gate and has to go around for another pass.

Most of the European airships have large logos emblazoned on their sides: Fujifilm; Astra; Le Matin; 24 Heures. All are supported by corporate sponsors. In some cases, the pilot owns the airship and contracts with the sponsor, who may cover maintenance and flying costs and sometimes even a salary for the pilot. Or the corporation owns the airship or enters into a partnership with the pilot. Corporate money pays for nearly all airship operations in Europe.

steering your easy chair around the sky. It's a misty morning over Ottawa, and some of the other airships are still on their way back from the targets at Rockcliff airport across the river. They seem ghost-like until they get close and then bloom into color.

Boland's "smaller and cheaper" airship is a technical and philosophical departure from the mainstream of airship owners. "If you and your wife want to take a balloon or an airship and take off for an afternoon of fishing, you should be able to do that without a crew of six people to help you get it going," he says. His goal is to design balloons and airships for the rest of us, unlike the monoliths produced by European manufacturers. *Dave*'s single-seat gondola is a lightweight recreational para-plane car with a superstructure added to support the pressurization engine and burners. Next to the sleekly contoured Thunder & Colt machines, it looks squarish and homemade. But Boland's entire airship can be broken down into packages that will qualify as baggage on an airliner. The typical commercial machine requires a 15-foot trailer. All of the European competitors' trailers were flown to Ottawa on a huge Antonov An-124 transport.

The commercial

In the United States, thermal airships are not yet well enough known to attract corporate sponsorship. Gas blimps are the standard for that kind of advertising. Thermal ships are not capable of either the speed or the sustained flight of gas blimps. With a full load of propane they can remain aloft for about three hours max, and, at a top speed of 15 knots, they must be transported to most locations by trailer.

Frank De Bock, owner of the Belgian airship, has the newest and, he argues, most advanced machine, a hybrid with a German GEFA-Flug envelope, a Thunder & Colt car, and a 65-horsepower engine. Its shape is slimmer because nylon panels divide the envelope into compartments, unlike ships in which the envelope is one big bag. "The temperatures vary from one compartment to another and that makes for a very stable ship," says De Bock. "The disadvantage is that it's more expensive to operate. Because of the slimmer shape, the top of the envelope gets hotter because it's closer to the burner, so the whole top section has to be replaced every 300 hours and the dividers inside every 75 hours."

De Bock offers me a ride. A couple of quick moves with the seat belt and the headset and I'm in the air with pilot Benoit Simeons, marveling at the sensation of floating like a hot-air balloon but with the ability to change direction without changing altitude. In the light five-knot breeze this morning Simeons can turn us around in about the length of the airship, 140 feet.

Since the car is only as wide as the seat and there are no sides to speak of, visibility is almost unlimited. With the headset on I can barely hear the clatter of the propulsion and compression engines, so it feels like

CHAD SLATTERY (4)

Rick Wallace buys used equipment from European airship owners who are moving up to the latest models. Americana*'s gondola isn't as sleek as its newer counterparts, but it's a lot more affordable.*

airships have panels with a standard set of instruments: altimeter, envelope temperature and pressure gauges, engine oil, starter buttons for the engines, radio and intercom. Boland has no instruments and starts the engines with pull cords. His motto is "Use what you have and make it work." The gas tank for the pressurization engine is a two-liter Coke bottle, and the tank for the two propulsion engines is a five-gallon translucent plastic can that allows him to see the fuel level. The ignition for the two engines is wired to toggle switches under the seat. When he pulls the throttles all the way back, they trip the toggles and shut down the engines for safety during landing. *Dave* has cost Boland about $5,000, most of it in materials for the envelope. But that wouldn't be an accurate estimate for most homebuilders. Boland already had two propane tanks, each worth about $1,500. He also had the propane burners, worth about $2,000 each. The para-plane car, which collapses to fit in an automobile trunk, was donated. The pressurization engine is borrowed from a snowblower. Even so, Boland is far ahead of the game. Standard commercially built thermal airships sell new for $100,000, and specialized models can cost twice that.

A thermal airship is the result of mating a gas blimp with a hot-air balloon. The envelope is inflated with hot air and provides lift as well as a rudder for steering; a piston engine provides propulsion. Most thermal airship pilots are also balloonists.

Rick Wallace of Santa Monica, California, has taken a different flyway into thermal airships. A retired police officer, he can't afford a new ship. He buys used equipment from Europeans who are trading up to the latest models. The 90,000-cubic-foot envelope on *Americana*, measuring 105 feet long, isn't quite as sleek as some of the newer ships, and the hefty 852-pound car with side-by-side seating is square and heavy. A 48-horsepower Honda motorcycle engine gives the craft a cruise speed of 15 mph, average for most airships. *Americana* has a reasonably full instrument panel comparable to those on newer airships.

When Wallace first brought his airship back from Europe, I watched him fly it in Temecula, California, about a month after watching Boland's "champagne flight." Wallace's was not nearly as successful. In the early stages of inflation a section of the envelope was trapped beneath a gondola wheel and ripped before anyone could get it loose. The five-foot tear was enough to degrade the performance but not

enough to stop the flight. Just before liftoff, a corner of a tarp laid on the ground to protect the envelope during inflation was sucked up into the propeller of the propulsion engine. No real damage, other than frayed nerves.

Once airborne, Wallace practiced maneuvers. As with hot-air balloons, descents have to be anticipated, and Wallace was having problems slowing his descent enough to prevent a couple of very bumpy landings. Finally, when he tried to make a turn at the end of the field with not quite enough altitude, the gondola got hooked on a chain-link fence. As the car stopped suddenly, the envelope dipped forward over the fence. The rebound of the envelope allowed the car to float free and Wallace was able to get above the level of the fence. No one opened the champagne.

Americana is performing much better at the championship trials than it did in Temecula, but *Dave* is doing worse than it did on its inaugural flight. Boland is having continual trouble with his steering lines, which twist and eventually tangle.

The third launch of the championship occurs on a weekend when there will be larger crowds, so one of the marker targets has been set up on the field here at La Baie Park, where thousands of spectators can see at least one attempt by each airship. This morning's weather briefing had reported winds at 10 knots, but by launch time the airships are facing only four to six knots, a more comfortable environment for airships that cruise at 15 knots. Race officials have set a 45-minute window for airships to get through the start gate. After completing their tasks, they must return through the same gate within 75 minutes. A championship must include at least four launches, each comprising a combination of tasks.

The first ship lifts off at 7:50 a.m. Soon several others, including Belgium, Germany, and Czechoslovakia, are waiting in line for the first target. Wallace lifts off, but Boland waits. He doesn't want to waste fuel standing in line. But he waits a bit too long. When he tries to start his propulsion engines, one is sluggish and the other one won't start at all. A crew member pulls on the starter cord until he's bathed in sweat while Boland tries various combinations of choke and throttle. The 8:30 start deadline is approaching, and competition director Gary Lockyer stands in front of Boland's car holding up three fingers: three minutes to closing the gate.

Another member of the crew takes over but the engine still resists. When Lockyer flashes two fingers, Boland makes a decision. They've had trouble with fouling spark plugs and he shouts for a new one. About 30 seconds before the deadline, a crew member pulls on the cord again. One pull. Two. Three, and the engine starts. In a couple of seconds Boland is off the ground.

By this time, the other airships have finished with the first target and some are already approaching the targets across the river. Boland makes a good approach in a quartering wind and tosses his marker into the second circle of the target. He gains altitude and makes the turn to head out across the river, but then the airship starts dropping rapidly. We can see that he's headed in the general direction of an enclosure containing the fireworks for tonight's opening of the hot-air balloon festival. He misses the fireworks and disappears behind some trees.

JOSEPH BOURQUE (2)

ADRIAN WYLD

When we arrive, Boland is untangling himself from the car. He's fine, but one corner of the car is embedded in the ground and the steering ski on that side is broken. "We can fix that with a little wood," he says. "I think the steering lines got tangled up and depressurized the bag." Later, at the hotel, he grafts a piece of oak flooring to the broken ski. Louise wants to cut off the excess length of the plank, but Boland, the former art teacher, resists. "No, I like it like that. Let's use it." And he hangs a running shoe on the protruding end.

To enhance the steering line for the championships, Boland added cross-country skis to his homebuilt (top). But competitors left him in the dust (above) when his upgrade hindered rather than helped.

Because of bad weather, there have been fewer launches this year than in past championships. The final event is a race from La Baie Park to an industrial park about 25 miles away. With headwinds at about 10 knots, only the ships with the biggest engines will make it. Of 16 that leave the ground, only five cover the full course. Rick Wallace and a couple of others manage to make it back to La Baie, but some are blown so far off course that they are forced to land in uncharted territory. Two airships land in a graveyard; the Czech entry knocks over a number of gravestones in the process.

Boland is still having trouble with his steering mechanism and has to land on a golf course a couple of miles away—better than a graveyard but a bit of a shock to the two guys at the tee when their view of the fairway suddenly disappears in a huge block of pink and green. Boland discovers that his steering problem is caused by the twisting pulleys on the tips of the skis. They should have been fixed pulleys.

In the end, a Swiss team places first. Jacques Besnard and his brother Phillippe have been competing against their father, Charles Besnard. Their *Le Matin* and Charles's *24 Heures* are nearly identical Thunder airships. But Jacques makes the better moves and takes first while Charles places fifth. Benoit Simeons with Frank De Bock's Belgian ship comes in second. Wallace places a respectable 11th, better than any U.S. competitor in at least the last two championships. Boland and John Addison, the third U.S. competitor in the championship, place 15th and 16th.

All of the crews have local people to help out. Lucien Tessier says: "With Brian, it's a question of trying to figure out where he's going to crash so we can get there." While that sounds a bit harsh, it's said with affection, even admiration. Boland is seen as a daredevil. Indeed, he holds the altitude record for airships: 16,598 feet (think about getting up to that altitude in an open car).

Though this has been a successful championship event and the display of airships was impressive, everyone involved is concerned with promoting the sport. At last count less than 40 thermal airships in the world were flying regularly. Whether they will ever catch on with U.S. corporate sponsors is unclear. Boland has translated his "smaller is better" motto into a marketing image: the Pocket Blimp. He distributes his own handouts with all the specifics and costs. No takers so far.

The Seventh World Hot-Air Airship Championship will be held in Austria in the year 2000. For now, the fishbowl is empty and all the fish deflated. Boland is already making plans for his next creation. "It'll be even smaller than this one and simpler," he says, "but it will carry two people. And it's going to be in the shape of a fish. And I'm going to build it so it even wiggles like a fish. It's going to be a convertible. I'll be able to fly it either as an airship or a balloon, depending on which car I put on it...."

Among the traits that thermal airships share with their hot-air balloon cousins is an appearance that would blend seamlessly into Macy's Thanksgiving Day parade in New York City.

BRING ME THE TAIL OF WILD-2

New space probes are grabbing pieces of comets and retrieving scraps from space.

by Michael Milstein

Illustrations by Paul DiMare

For nearly 20 years, Peter Tsou has longed to catch a bit of the heavens and return it to Earth. In 1981, he and his colleagues at NASA's Jet Propulsion Laboratory in California suggested a space mission to capture dust samples from Halley's comet on its 1986 swing past Earth. But NASA balked at the estimated $300 million price tag and turned it down. Tsou's team proposed other comet grabs only to see those rejected too. Next they pitched missions to gather interstellar dust. Rejected. A joint comet mission with the Japanese. Rejected. Twelve missions all together, all turned down.

"I have a JPL report!" fumes Tsou, a rail-thin man who never seems to sit still. "The JPL gurus said it couldn't be done!" He yanks open and then slams shut the drawers of a metal file cabinet in his cramped office, but can't find the offending document. "I might have thrown it away I was so disgusted!"

Despite the naysayers, Tsou pressed on, moonlighting in his lab to keep his comet-catching dreams alive amid other assigned engineering work. He scavenged dials and electronics headed for the trash heap and built control panels of plywood in his search for a novel way to retrieve samples of cometary dust. Then he started experimenting with a substance called aerogel, which he realized would be the perfect catcher's mitt for the ultimate fastball—comet fragments moving at speeds up to ten miles per second. Eventually Tsou teamed with astronomer Donald Brownlee of the University of Washington to propose a mission called Stardust, which would use aerogel to trap dust particles from a comet named Wild-2 (pronounced "Vilt-2").

He steeled himself for more rejection. But in 1995 NASA chose Stardust from a field of 28 proposed missions for the agency's Discovery planetary exploration program. In early February, Tsou's spacecraft will be launched from Cape Canaveral aboard a Delta II rocket, the first in a series of inventive spacecraft that will take humankind's penchant for souvenir collecting beyond our little corner of the solar system. The missions will grow in complexity and ambition. While the first will sweep up comet dust and atomic particles streaming from the sun, later spacecraft will land on an asteroid, a comet, and Mars and possibly its moons, where they will drill or blast handfuls of material to bring home. If they succeed, the missions will let planetary scientists finally hold objects they've always had to study from afar.

"The point of sample return is to flip the paradigm," says Kenneth Atkins, an engineer and former Air Force pilot who is now Stardust's project manager. Traditionally, space researchers load planetary spacecraft with hundreds of

January 2, 2004: Stardust zips past Comet Wild-2 at four miles a second. A tray of aerogel extends upward like a flyswatter, trapping dust as it passes.

millions of dollars' worth of remote sensing instruments, which then send back limited amounts of data during frantic "fly-bys." Most scientists will tell you it isn't the best way to do research.

But, says Atkins, "if I can bring back a sample and hand it to you, there's no limit to the science you can do. Nobody has to compromise their science. We're not trying to haul everything up there. We're just bringing the mountain to Mohammed."


KEITH SKELTON

Genesis project manager Chet Sasaki hopes to use arrays of ultra-pure silicon wafers to collect five billion-year-old atoms. Stardust's magic material, aerogel (below), is light and strong, and also a good insulator. Japan's MUSES-C mission (opposite) will fire a pellet into an asteroid and sample the dust that flies up.

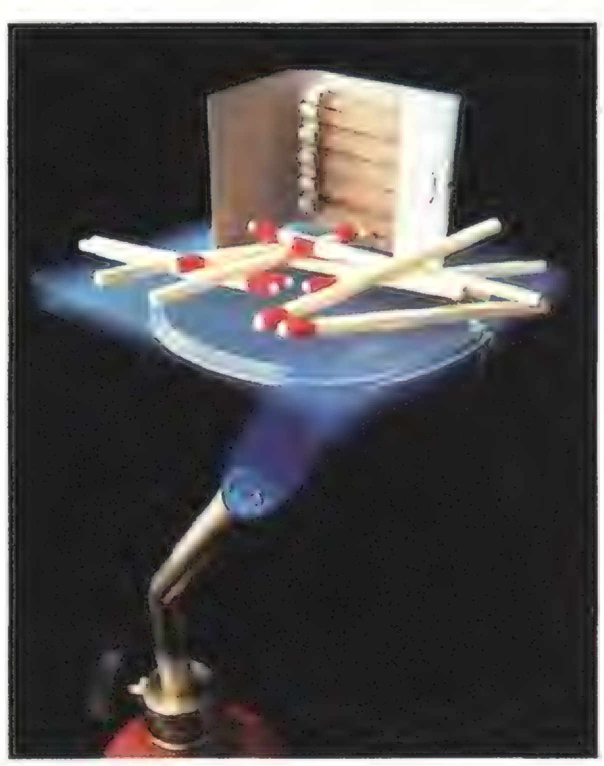
Chet Sasaki, project manager for a JPL mission called Genesis that aims to retrieve atomic particles streaming from the sun, points to another advantage of sample return. Scientists on the ground will be able to study extraterrestrial material with isotope analyzers and other state-of-the-art equipment, and won't be limited to the simple tools they can afford to send into space. "We have some tremendously useful instruments on the ground that you could never fly, at least not with current technology," he says. "You think, 'Too bad we couldn't do one more experiment because it might have told us what we really wanted to know.' "

For all their desirability, sample return missions have so far ventured to only one place: the moon. Luna 15, a last-ditch Soviet attempt to steal thunder from the Apollo 11 mission in July 1969, was supposed to land and return lunar soil to Earth before the U.S. astronauts could make it home. Instead the unmanned probe crashed into the surface on July 20, the same day Neil Armstrong and Buzz Aldrin touched down at Tranquillity Base. Apollo astronauts eventually lugged 842 pounds of moonrocks back to Earth, while three succeeding Soviet robotic landers drilled into the moon and carried back a paltry 10 ounces or so of material.

But ironically, it is the Soviet missions, not the Apollo expeditions, that are the true ancestors of the new generation of sample return missions.

"The robotic missions did everything without any human help, which is pretty amazing considering the technology at the time," says David Williams, a planetary scientist at NASA's National Space Science Data Center, which maintains archives of data from past spaceflights. "At least in the near future, it's those kinds of unmanned missions that will bring back the goods."

Peter Tsou pulls open a desk drawer and grabs a small jar holding what looks like a thumb-size chunk of coal. It's a fragment of the Murchison meteorite, which streaked through Earth's atmosphere and landed near Murchison, Australia, in 1969. This small scrap of a comet's nucleus made almost as much of an impact on Tsou as it did on the Australian Outback. It doesn't seem like a menacing piece of space debris. It's soft and contains what scientists have identified as complex organic material, including amino acids, the stuff of life.


ROBERT M. BROWN, JPL PHOTO/IMAGING

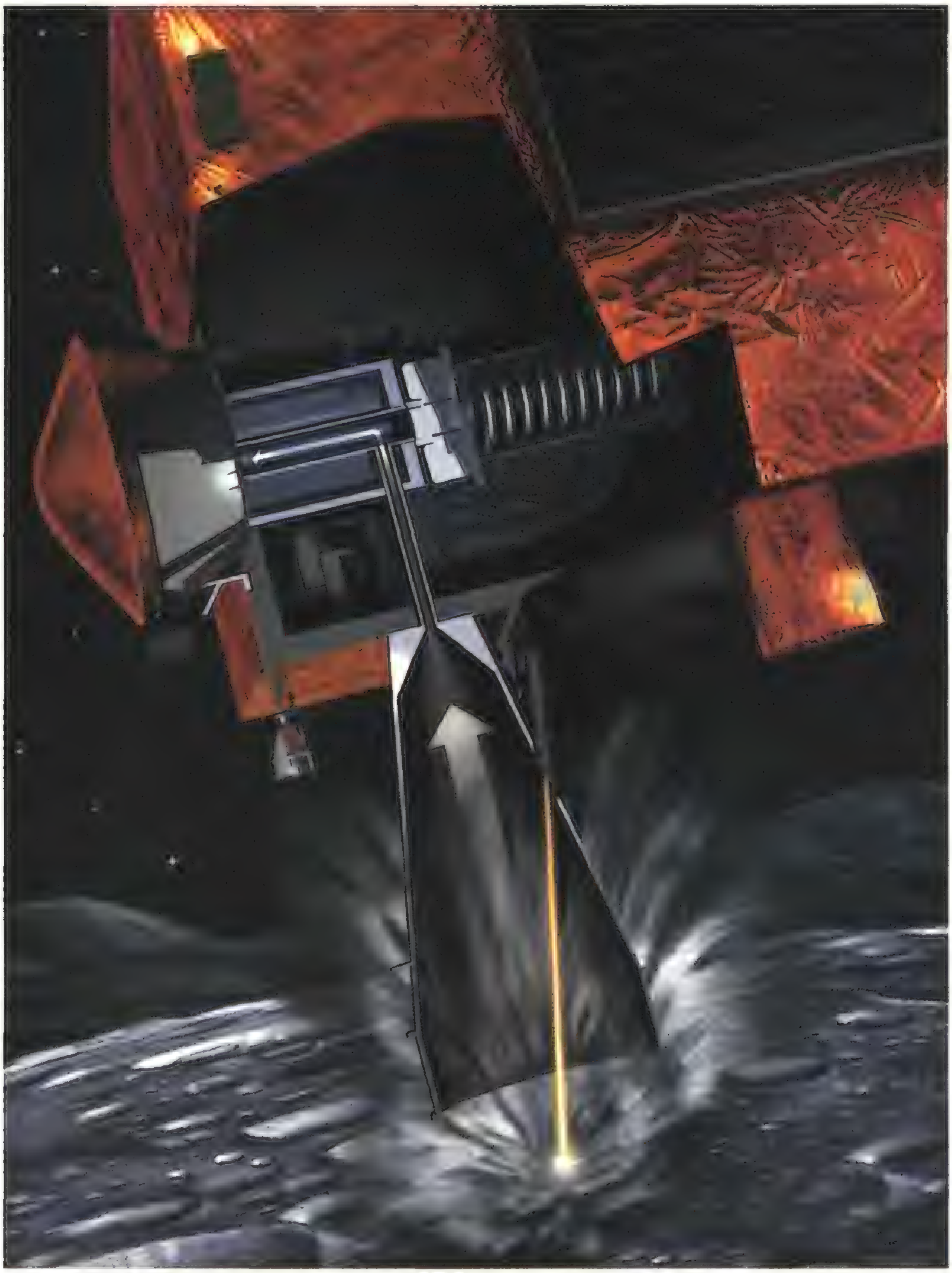
"This opened scientists' minds," Tsou says. Unlike planets and moons, which have been heated up and transformed over their lifetimes, comets are thought to contain nearly pristine material left over from the earliest days of the solar system. Since they also contain water and have been smashing into Earth since its formation, they may have filled our oceans. The organic material inside the Murchison meteorite raises a further intriguing possibility: that comets sowed the early Earth with the chemical seeds of life. "This may be a catalyst," Tsou says, pointing to his chunk of meteorite, "that starts a lot of things going on Earth."

To take the theory further, scientists would like a better understanding of the chemistry and mineralogy of comets in their natural state. Unfortunately, most objects that hit Earth's atmosphere disintegrate or are altered before they reach the ground. To get the real stuff, there's only one place to go—a comet.

Until very recently, the idea of landing on a comet nucleus seemed impractical. The fuel requirements to match orbits and then drop a spacecraft on such a small, poorly understood body made any mission risky and expensive. So several years ago Tsou took another approach to comet sampling. He planned to bring back the tiny particles that every comet sheds like dandruff on its way through space.

Even this is not as easy as it sounds. A rifle bullet moves perhaps 3,000 feet per second. Comets move at least 10 times faster. "How are we supposed to catch a speeding bullet without breaking it up?" Tsou wondered.

Sample return missions proposed in the early 1980s would have caught comet bits in much the same way a speeding car collects bugs: by smashing them to smithereens so the remains can be



scraped up. To Tsou, the method seemed as unsatisfying as unearthing an ancient vase, then having it crumble into dust. To understand comets in their natural state, you want intact dust grains, if only very small ones, that preserve the original mineral and chemical structure. "If I can return a chip, not the entire vase, I can make a contribution to science," Tsou remembers thinking.

In his search for a material sturdy enough to stop comet shrapnel but soft enough to avoid breaking it up, he tried various relatives of Styrofoam. "You name the foam, I've used it," he says. But none worked.

Then he came across aerogel, which had been discovered in the 1930s. Hold a cube of it in your hand and you hardly know it's there: It looks like smoke with sharp edges, weighs almost nothing, and has the texture of very delicate Styrofoam. Like glass, aerogel is made of silica, but it's 99 percent empty space, and is in fact the lightest solid known. Under the microscope its airy crystalline framework looks like strings of pearls. Yet a block of the stuff weighing less than a pound can support a small car.

Soon Tsou became one of the world's few experts on aerogel. He cooked up batches in his laboratory, and found that when a speeding particle plows into aerogel, it encounters just enough resistance to start slowing down. As it slows, the resistance increases until the missile comes softly to a stop.

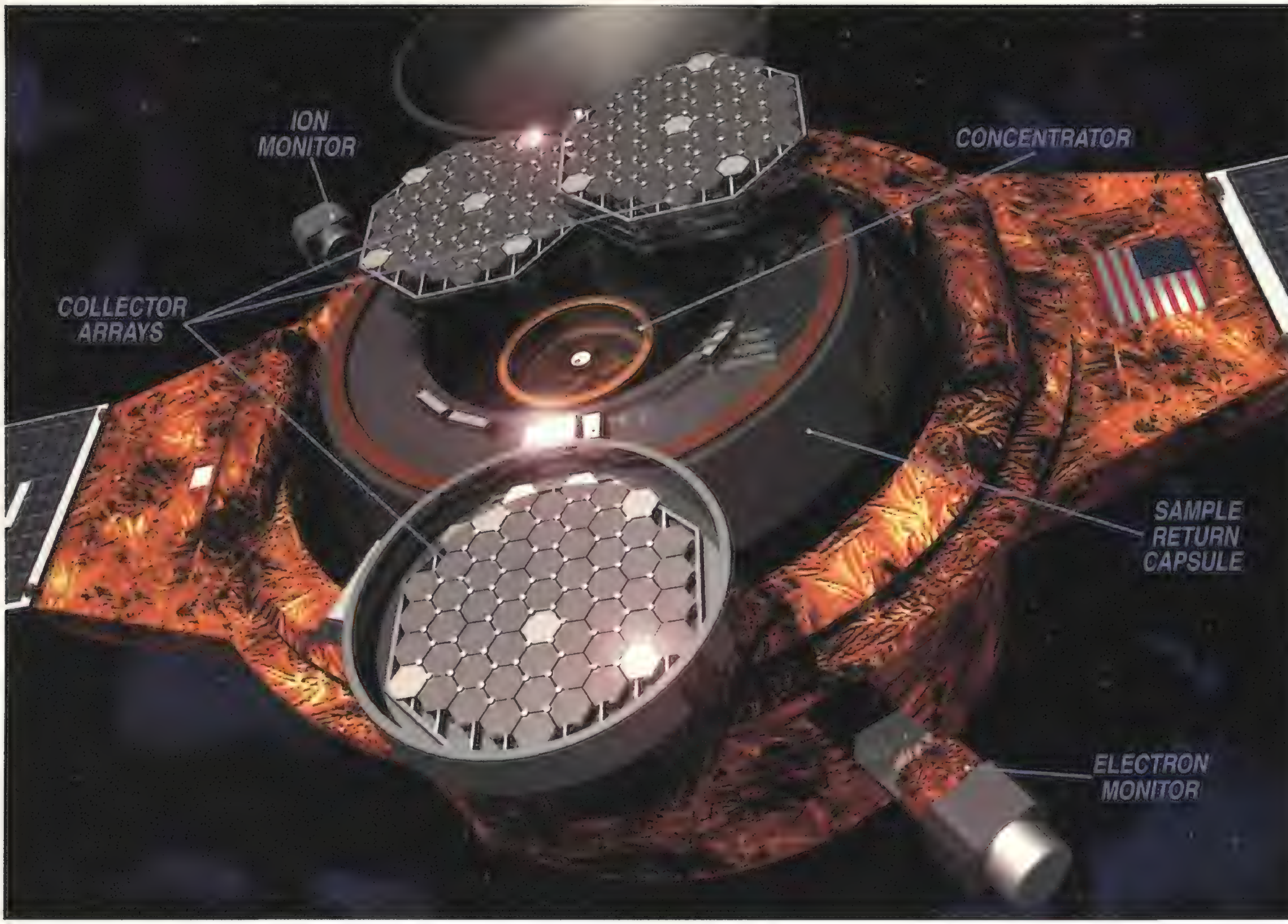
Using facilities at NASA's Ames Research Center in California, Tsou test-fired tiny projectiles into aerogel, and later had some of the stuff flown on the space shuttle, where it snagged a few extraterrestrial dust grains. Finally he had proof that certain formulations of aerogel could almost instantaneously catch and stop comet particles moving as fast as ten miles per second.

Meanwhile, Chen-wan Yen, Tsou's colleague at JPL, was searching for comets whose orbits lent themselves to a slow approach by a spacecraft. She found one called Wild-2, which had been circling in obscurity far beyond Jupiter until 1974, when the giant planet's gravity yanked it into the inner solar system. German astronomer Paul Wild first spotted it four years later. Even better for the Stardust team, Wild-2 is a relatively "fresh" comet, unscathed by many passes near the sun.

Yen devised a trajectory that will take the Stardust spacecraft on three loops around the sun over the course of seven years. The first loop includes a close pass and gravity boost from Earth, and the third brings the samples home in 2006. On the middle loop, the spacecraft's trajectory will intersect that of Wild-2, taking Stardust within 90 miles of its target on the sunward side.

Swooping down from above the comet's orbital plane at a relative speed of four miles per second, Stardust will extend a platter of aerogel to trap dust grains and heavy molecules as it moves through the comet's coma of gas and dust. (Earlier in the mission, as a bonus, it will also try to snag smaller and faster-moving dust particles that are constantly streaming into the solar system from interstellar space.)

For several hours on January 2, 2004, when it's sweeping through the cloud of gas and dust surrounding Wild-2's two-and-a-half-mile-wide nucleus, Stardust will brave the kind of storm that knocked the European Giotto spacecraft out of whack during its 1986 rendezvous with Halley's Comet and caused it to send a stream of data into deep space instead of to Earth. Whipple Shields—bumpers made of layered graphite composite material—will protect Stardust's leading edge by doing to oncoming comet particles exactly what Tsou has struggled not to do: vaporizing them. An onboard camera will snap pictures of the nucleus through a periscope so the lens never looks di-



rectly into the eye of the storm.

A particle only a half-inch in diameter could put Stardust out of commission. The scientists are hoping to trap much smaller quarry: at least 1,000 comet particles upward of 15 microns in diameter, or about one-fifth the width of a human hair.

No fools, they've set the encounter time for three months after Wild-2 rounds the sun, when the comet is still spewing dust and gas but is past its peak. "We have to get close enough to get a sample, but not close enough that we get killed," says Brownlee.

Then comes the journey to Earth. All the currently planned sample return missions will bring back their treasure the same way Stardust will. First they will stow their samples inside clamshell-like capsules that clamp shut and lock like a bank vault. The motherships will then ferry the capsules, which are shaped like toy tops, back to Earth and jettison them, spinning like a rifle bullet for stability, into the atmosphere.

Heat shields, built by Lockheed Martin Astronautics and similar to those used on Mars landers, will protect against the heat of reentry. The Stardust capsule will hit Earth's atmosphere at 28,000 mph—nearly twice as fast as the space shuttle does—and will free-fall for about two miles, its shield heating up to 4,000 degrees Fahrenheit.

After the free-fall a small drogue parachute will open to keep the craft upright. As the vacuum-packed capsule drops through the atmosphere, it will feel the same sort of increasing pressure that squeezes a submarine on its way to the ocean floor. The only solution to this problem that engineers have come up with is to build vents in the capsule that allow Earth air inside, equalizing pressure during the descent. Because scientists want to keep the precious cargo as pristine as possible, a filter will screen the incoming air. As soon as possible after the capsule lands, technicians will pump it full of pure nitrogen gas, purging the outside air.

In the final moments of descent a larger parachute will open and brake the capsule's speed to about 15 feet per second so that it lands in the Utah desert with about the impact of a typical skydiver. Researchers will track the homecoming on radar, and a helicopter recovery team will follow a beacon on the capsule to welcome it back from its seven-year, three-billion-mile journey.

Genesis uses two monitors to gauge the solar wind's changing speed and character, then picks the right collector array for the circumstances. Opposite: Peter Tsou, with his own collector grid.

The next sample return mission in the queue is due to launch in January 2001. Called Genesis, it will chase the solar wind in search of material even more elusive than comet dust.

About five billion years ago, a vast cloud of gas, dust, and ice collapsed into a spinning nebula, the platter-like ancestor of today's solar system. All but a tiny amount of this material slid into the calm middle of the vortex and formed the sun, while a few leftover crumbs agglomerated to become the planets, comets, and asteroids. Studying the el-

The Poor Man's Stardust

As crazy as Peter Tsou is about aerogel, David Noever may be even crazier. Give him a chance, any chance, to fly his "solid smoke" in space and he jumps all over it.

The head of a three-person aerogel research team at NASA's Marshall Space Flight Center in Huntsville, Alabama, Noever had the first aerogels produced in space (they grow more uniformly there) during a seven-minute sounding rocket ride in 1996. Last October, he gave John Glenn some of the stuff to experiment with during his space shuttle flight. A month later, he attached a few ounces of aerogel to the outside of a weather balloon launched by another team at Marshall, and sent it up 100,000 feet in the hope of capturing dust from the annual Leonid meteor shower, a trail of trash left in Earth's orbital path by the comet Tempel-Tuttle. The odds of success, Noever estimated beforehand, were less than 10 percent.

Locating the sample return package afterward was half the fun. Local amateur balloon trackers homed in on its radio beacon a day later some 200 miles from Huntsville, in Chatsworth, Georgia. More precisely, it landed in a briar patch behind Homer's Yarn and Textile Sales (Homer Dills, proprietor).

Noever's el-cheapo ($300) mission returned a total of 32 samples, which he immediately set to analyzing under an electron microscope. They appear to be mostly silicon and oxygen, but determining their origin may be difficult, considering the almost random way in which they were collected. Even if they don't turn out to be pieces of Tempel-Tuttle, he figured it was worth a shot. Wouldn't it be nice, he muses, to "return the first material from outside the orbit of Saturn?"

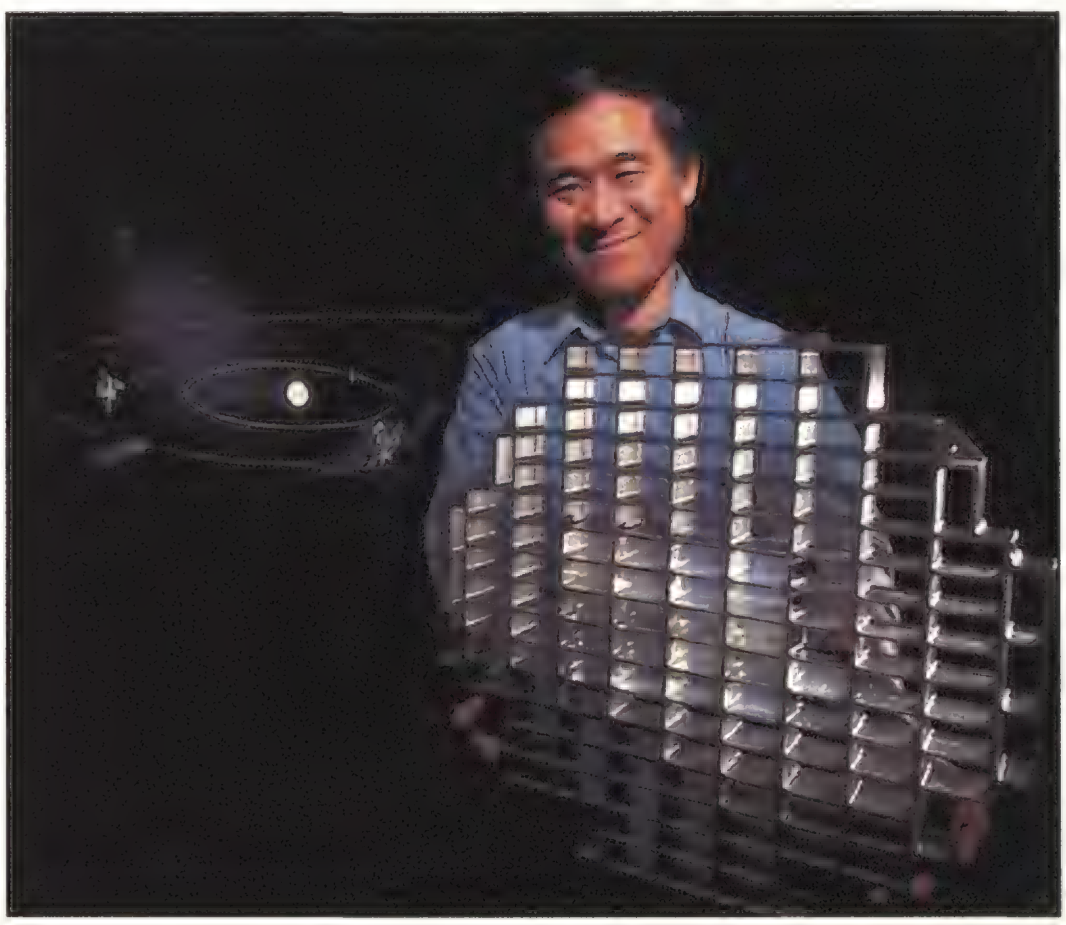
Of course, he doesn't claim to be competing with Stardust, which aims to come back with intact cometary material fresh from the source. "We have a really different set of goals," he says. But he'll probably try his luck again during next year's Leonids, or any other meteor shower for that matter, as long as he can cadge a cheap ride. The Leonids opportunity, Noever said before the balloon launch, was "like room service for science. Instead of us going to the comet, it's coming to us."

—*Tony Reichhardt*

emental makeup of today's solar system is like reading the last chapter of a novel and trying to guess everything that happened before.

All the original characters are still there, though—not inside the sun, where nuclear fusion has scrambled the evidence, but in its outer layers. Pristine samples of the solar nebula should still be found in the million-mile-per-hour stream of charged atoms known as the solar wind, which boils continuously from the sun's surface.

Previous spacecraft have gauged this wind like a traffic counter tallies vehicles on a highway, without bothering to distinguish among cars, trucks, and motorcycles. The $216 million Genesis mission will return samples so scientists can sort out the different elements and isotopes.



KEITH SKELTON

Because Earth's magnetic field deflects the solar wind from the planet, the spacecraft will be sent to a far–off location between the sun and Earth known as the L1 libration point, where the gravitational tugs of the two bodies are in balance. There it will open the top half of a clamshell-like container crowning the spacecraft, exposing ultra-pure silicon wafers to the solar wind. Atoms of helium, oxygen, nitrogen, and the other, still unconfirmed elements from the original solar nebula will plunk into the wafers like darts in a dartboard. An electronic concentrator will serve as a magnifying glass, focusing particles of interest onto collecting targets. Since the samples are lightweight atoms, the impact won't rattle the spacecraft in the slightest.

Stardust and Genesis use a straightforward method of sample return, grabbing their samples on the fly. Landing a spacecraft on an asteroid or planet, then extracting a chunk of material and bringing it home, is a much trickier job.

In January 2002, a Japanese mission called MUSES-C (an acronym standing for Mu, the name of the launcher; Space Engineering Spacecraft; and C, the third craft of its class) will set a course for a mile-wide asteroid called Nereus. Like comets, asteroids are leftovers of the early solar system. But the water in some asteroids has long since boiled away, leaving only rock. After inspecting Nereus for promising landing spots, the boxy MUSES-C craft will pull up to within 150 feet of the asteroid and deploy—or, rather, drop—a small NASA-built rover the size of a Tonka truck.

MUSES-C scientist Donald Yeomans, a leading expert on asteroid and comet orbits at JPL, demonstrates by palming a model of the little camera-toting rover like a basketball. Then he lets it go and clicks his tongue.

"Just free-fall," he says.

Nereus is so small its gravitational pull is 100,000 times less than Earth's. That eases any worry of a damaging crash landing. But Ross Jones, the rover project manager at NASA, wants to make sure the microrover doesn't hit a bump and launch itself into outer space, "like Michael Jordan jumping in slow motion," so its speed will be limited to a fraction of an inch per second.

Drifting over the sur-

face, the main spacecraft will use an imaginative but unproven technique to grab its samples. First it will fire a steel bullet out of a funnel-shaped "collection horn" that looks like an elephant gun. Chunks of asteroid loosened by the impact will then fly like shrapnel up the funnel and into a chamber at the narrow end. Three such collection chambers and a revolving cylinder like that on a pistol will give MUSES-C enough ammo to blast out three separate rocky showers. NASA's rover may later trundle over—but not too fast!—for a close look at the wounds.

Since no one has ever tried to snatch a piece of asteroid, let alone blast away at one, MUSES-C is riskier than tried-and-true fly-by missions. "It's more complicated, so you need more resources and more can go wrong," says planetary scientist Joseph Veverka of Cornell University in New York. "But it's also very necessary, so you have to take those risks." Veverka is a fan of sample return, even though his own NASA-sponsored mission, called Contour, will take a more traditional approach to studying comets, flying past three of them following a 2002 launch.

The most obvious place in the solar system to send a sample return mission is Mars, a close cousin of Earth that may once have harbored life. NASA's long-term Mars exploration strategy in fact culminates with the arrival on Earth of a kilogram or so of Martian rocks in 2008. They may not be the first samples to arrive from that vicinity, however, if a mission called Aladdin is selected to launch in 2003. One of five Discovery proposals chosen last year for further study, Aladdin would return pieces of the planet's moons, Phobos and Deimos.

Like MUSES-C, the spacecraft would fire projectiles and trap whatever soil and dust kicks up from the surface. Its return capsule would be a scaled-down version of the one flying on Stardust. Aladdin's innovation, and the inspiration for its name, is a flexible sample collector that would unroll like a carpet to catch the rain of samples, then scroll up again to protect the prizes from contamination. If Aladdin's carpet flies, it will be the first to return samples from another planetary system.

You could say that Brian Muirhead has already been to Mars. As leader of the Mars Pathfinder team, his were among the loudest whoops of joy heard when the craft bounced to a stop in Ares Valley on July 4, 1997. Muirhead now heads a JPL team that's designing a more ambitious mission to even less familiar territory.

"Meet Monsieur Champollion," he says, gesturing at a glistening structure of boxes, globes, gold foil, and wiring about the size and shape of a large trash can. Sponsored by NASA's New Millennium Program to test sample return technology, the spacecraft goes by the formal name of Deep Space 4 but is known more fondly as Champollion, for the Frenchman who deciphered the hieroglyphics of the Rosetta Stone.

Muirhead is after the same quarry as Peter Tsou—the stuff that makes up a comet. But his project shows how far space technology has advanced since Tsou began his Stardust campaign in the 1980s. Champollion's goal is to take samples from a comet called Tempel 1 in a way Tsou once considered impractical: landing on its nucleus in 2005 and drilling about three feet below the surface. Since no spacecraft has ever been within 100 miles of a comet before, no one is sure whether it will be drilling into hard ice or loose snowdrifts, or whether it can survive the dust storm close to the nucleus. "We just don't know," Muirhead says in a tone that suggests he's rather proud of his ignorance. "This is ex-

KEITH SKELTON

Above: Silicon arrays on Genesis are too delicate to hit the ground, so a helicopter will grab the capsule's parachute in mid-air. Brian Muirhead (right) faces an assignment even tougher than the Mars Pathfinder landing he pulled off in 1997—anchoring his Deep Space 4 spacecraft to a comet nucleus, then drilling out samples (opposite).

ploration of the first order. This is Lewis and Clark. This is Columbus. This is going someplace for the very first time and no matter how well we plan, we are going to have to adapt."

To anchor itself to the comet, Champollion's lander will fire a telescoping harpoon that pulls the spacecraft to the surface, whatever form that surface happens to take. Then it will drill out a few samples with the approximate combined volume of a Ping Pong ball.

Because this is a technology demonstration rather than a full-up science mission, Deep Space 4 is likely to stop right there. Taking the next step and returning the samples to Earth is probably not in the cards, according to Muirhead, who says it comes down to pluses and minuses. The pluses are wholly scientific: DS-4 will go after much more substantial samples than Stardust will, and closer inspection of the comet would put the specimens in better context. Secondly, the samples will be raw chunks of the comet's insides rather than dust that has been exposed to space.

The minuses have to do with money: Bringing the samples home demands a round-trip ticket, which extends the mission, requires more fuel and larger solar arrays, and could double the current $160 million price tag. Muirhead levels his hands in the air as if weighing the benefits of sample return against the financial risk, then drops the risk hand toward the floor. "There's only so much we can get off the ground," he says.

Then his enthusiasm revives. Even if Champollion doesn't haul back a piece of Tempel 1, he says, experience with the spacecraft's lander and sampling equipment will pave the road for future sample returns.

After Mars, comets, and asteroids have been sampled, that road will become rough indeed. Which is why Kenneth Nealson, a microbiologist leading a new biology division at JPL, is not optimistic about the near-term future of sample return, beyond those missions already in the works.

"I will absolutely love it if we bring a sample back from Mars, but I think we have to agree that after Mars it gets really difficult," he says, as construction workers build his laboratory around him. Getting a piece of Jupiter's moon Europa, which offers tantalizing hints of an ocean underneath its shell of ice (see "Surfing the Solar System," Dec. 1997/Jan. 1998), would take about 12 years, round-trip.

Nealson believes space exploration in the near future will therefore depend mostly on remote sensing. "I think it's absurd to think sample return is going to be a big part of it," he says. "You're better off to make something that sends you back data. If you find something, then the next generation can muster the support for a sample return."

Among the many risks facing sample return spacecraft is the trauma of coming home. The Genesis capsule's return to Earth will work something like an aerial fishing derby. As the craft parachutes down toward the Utah test range, a helicopter with what looks like a fishing reel on its belly will snag the chute and reel the capsule in, sparing it the shock of impact.

By the time Genesis comes home in 2003, a new generation of missions could be on the drawing board—maybe even ones that can solve the financial and technical difficulties of bringing back samples from the outer solar system. If Peter Tsou's quest for a piece of comet has taught him anything, it's patience.

"Got a good idea?" asks a sheet of paper tacked to the wall of his office. "Be persistent for a decade or two!"

Lost at Sea


DAVID POVILAITIS

"Where are the carriers?" For nearly half a century, that has been the question asked by the President's National Security Council advisors whenever there has been a crisis or conflict affecting U.S. interests almost anywhere in the world. The United States has repeatedly dispatched its aircraft carriers to demonstrate its will to take action, as was evident recently in response to Iraqi intransigence. In some instances, a carrier's presence has been enough to avoid a fight. However, if aircraft carriers are to continue to have a major role in U.S. national security considerations, the Navy must reverse its recent decision on "flat-tops."

Today the U.S. Navy has 12 large aircraft carriers in service—three with oil-burning turbines and nine with nuclear propulsion. Another nuclear carrier is under construction (to replace one of the older ships). All but one of the "nukes" are *Nimitz*-class ships, each displacing up to 98,000 tons at full load, operating some 80 aircraft, and carrying a crew of more than 5,000 men and women. The current *Nimitz* design evolved from the first "super carrier," the *United States,* of some 80,000 tons, which was laid down—and canceled—50 years ago. Each super carrier built since then has had some improvements over its predecessor, but there have been no truly new designs.

In 1996 the Navy initiated a program to develop the next-generation aircraft carrier—given the designation CVX—which would be a major divergence from previous designs. The first ship of the new class was to be funded in fiscal year 2006 and join the fleet about 2013. The CVX promised faster operating cycles for advanced aircraft, lower detection signatures (and hence enhanced survivability), decreased manning requirements, and significantly lower construction and operating costs.

Disregarding this promise, the Navy killed the program. This was a short-sighted decision, ignoring both the increased vulnerability of our current carrier fleet and the technological advances that will force changes in the aircraft carrier's role.

Aircraft carriers have been invaluable because of their great mobility, their ability to operate aircraft without the political restrictions that inhibit the use of foreign bases, their flexibility in being a "presence" or strike platform with high-performance aircraft, and their ability to remain "on station" for essentially unlimited periods through at-sea replenishment. But despite their proven efficacy, aircraft carriers have also been criticized for vulnerability to detection and attack. While past critics were often wrong, the vulnerability issue is becoming critical because of the increasing availability of satellite surveillance systems and the proliferation of improved missiles and torpedoes. The CVX, with its vastly decreased radar cross-section, as well as much more effective self-defense systems, directly addresses these new threats to the survivability of current aircraft carriers.

Earlier, most carrier critics were brushed aside because the ships and their aircraft continued to demonstrate their effectiveness. Today, however, the viability of aircraft carriers is also being questioned. Alternative systems, including satellites and unmanned aerial vehicles, can perform reconnaissance and airborne early warning. Unmanned aerial vehicles can perform these and other roles, eventually including fighter and strike missions.

Guided or cruise missiles, which do not place a pilot's life at risk, are already in service on board 22 cruisers, more than 50 destroyers, and 50 submarines, and those missiles can strike targets at ranges of several hundred miles with an accuracy of several feet.

However, it is clear that the United States still needs manned aircraft to carry out certain types of strikes. By about the year 2010 the non-stealthy F/A-18 Hornet will be the only fighter/strike aircraft on U.S. carrier decks. The so-called Joint Strike Fighter (JSF), a semi-stealthy fighter/strike aircraft, will begin joining the fleet a few years later. However, production of that aircraft is not a certainty and will probably be delayed as the Navy tries to apply all available near-term aircraft funding to the F/A-18 while the Air Force is trying to fund additional F-22 Raptor aircraft in

Current aircraft carriers are based on 40-year-old designs. Norman Polmar argues against scuttling an advanced flat-top.

the near term. The cost of the new F/A-18E and -F models of the Hornet and the increasing cost of maintaining aircraft make it impossible to realistically propose or plan carrier-based aircraft beyond the improved F/A-18 and updates of existing carrier-based radar warning, anti-submarine, and electronic jamming aircraft. The CVX, with its much more efficient deck and ordnance handling ability, could have greatly increased the effectiveness of even the non-stealthy F/A-18 and decreased turnaround times dramatically.

Specifically because of these issues, the Navy needs the CVX.

The CVX, according to the Navy's Director of Air Warfare, Rear Admiral Dennis V. McGinn, was being designed on a "clean sheet of paper" and would "feature improved characteristics in selected areas, such as launch and recovery equipment, flight deck layout, C^4I [Command-Control-Communications-Computers/Intelligence] systems, information networks, and propulsion systems." The new features would also be more affordable to operate.

These and other advanced carrier concepts, which directly address the growing shortcomings of the Navy's fleet of mostly *Nimitz*-class carriers, were being studied at the Carrier Innovation Center of the Newport News Shipbuilding Corporation in Virginia. The center was also examining non-nuclear propulsion concepts for the ship, primarily gas turbines, which would be cheaper (even including fuel costs) and require fewer crewmen with less specialized training than would a nuclear propulsion plant.

Fielding an aircraft carrier that employs modern automation—even to move heavy bombs and missiles to the flight deck—and thus requires a significantly smaller crew than a *Nimitz*-class carrier would result in tremendous long-term savings. Significant savings were also possible from the CVX's adoption of construction techniques pioneered by the commercial shipbuilding industry, which builds ships using modular sections that can be assembled into a full hull. Entire galley and living quarters can be custom-built and inserted into the ship. Internal ship communications, which traditionally involve stringing hundreds of miles of bulky wires and pipe, can be done with advanced techniques whereby fiber optics, which take up a fraction of the space, are literally blown through conduits to complete the installation.

The Navy, by decreeing that the CVX be nuclear powered, diminished many of the benefits.

Unfortunately, the Navy, by decreeing that the CVX had to be nuclear powered, diminished many of the benefits it originally offered. This decision, a result of the tremendous influence that nuclear power proponents enjoy within the Navy, affects the design of the entire CVX and contradicts the "clean sheet" concept that provided the opportunity to use cheaper-to-operate gas-turbine propulsion—or even a combination nuclear-gas turbine plant.

In undercutting the design of the CVX, the Navy never adequately planned for the more than $1 billion CVX design and development costs, and never adequately advised Congress of the total funding requirements. Still, Navy leadership continued to promote—although in reality, only half-heartedly—the CVX concept. The program continued to be underfunded by the Navy. Then, in the spring of 1998, Congress cut almost $100 million from CVX development funding and the Navy did not fight the reduction. Subsequently, a Navy official was reported as saying, "We just cannot afford the investment needed to achieve the hoped-for long-term savings."

In this way, the Navy scuttled the CVX. The next carrier, the as-yet-unnamed CVN-77, has now been described by the Navy as a transition ship between the *Nimitz* design and the CVX, a term still used as a public relations ploy. The CVN-77 will incorporate some new features, continuing the traditional process of incremental improvements to carriers. Subsequent large aircraft carriers—if such ships are built—will be generally similar.

In the current post-cold war budget environment, $5 billion-plus warships will be clearly more difficult to fund. It is also clear, however, that the CVX, while requiring a large initial investment, offers tremendous potential for long-term savings. Aircraft carriers will continue to remain a key component of U.S. political-military strategy in the near term, but the carrier's increasing vulnerability, the decline in its air wing capabilities, and the high costs of building and operating the *Nimitz*-class carriers—which will undoubtedly result in a reduction in the number of such ships in our fleet—demand an objective reevaluation of the current carrier design. As originally conceived, the CVX program offers us such an opportunity.

Norman Polmar is a well-known naval and aviation analyst, consultant, and author. During 1988 he was the Ramsey scholar at the National Air and Space Museum, where he revised his *Aircraft Carriers: A History of Carrier Aviation and Its Influence on World Events* (1969). He has written or co-authored more than 30 books.

INVENTING THE SPYPLANE
RECON

by William E. Burrows

The OXCART Cometh

And goeth at Mach 3.2

On May 1, 1960, Soviet air defense missiles downed a U-2 flown by Francis Gary Powers, and, with 24 missions flown, overflights of the Soviet Union were halted. America's first purpose-built spyplane had, until that day, avoided such a fate by flying extremely high, but the U-2 was slow, and U.S. officials had always known its days were numbered. If the airplane's follow-on was to be less vulnerable, and assuming the high-altitude requirement persisted, as it had to, then only one area of performance remained: speed.

Under a project code-named Gusto, the Lockheed Skunk Works, headed by the legendary Kelly Johnson, and the Convair division of General Dynamics completed designs for a successor to the U-2 in the summer of 1959. Convair proposed a manned, ramjet-powered parasite reconnaissance airplane that would be launched from a special version of the B-58B Super Hustler bomber flying at Mach 2.2 above 35,000 feet. The parasite would reach Mach 4.2 and 90,000 feet, according to Convair. The project, named Fish, was terminated because the Air Force canceled the B-58B and ramjet technology was unproven. Convair later came back with the ground-launched Kingfish, based on its F-106 Delta Dart interceptor and the B-58, but it too was doomed.

That left the Skunk Works entry, which had evolved from A-1 (for "Archangel") to A-11 and then A-12, which in turn evolved into the Air Force's SR-71. There is disagreement even today at the Skunk Works on whether the CIA's version was the A-11 or the A-12. Garfield J. Thomas, vice president of Reconnaissance Systems at what is now Lockheed Martin, says it was the A-11. Albert T. "Bud" Wheelon, who was head of the CIA's Directorate of Science and Technology in the early 1960s, agrees. Engineers at Pratt & Whitney who designed its engine claim it was really the A-12. They're all correct. Two Johnsons—Kelly in private and Lyndon Baines in public—called it the A-11. And the basic airplane was the A-11. It became the A-12 when its metal vertical tail, engine inlets, and the forward edges of its nacelles were changed to a kind of composite plastic to foil enemy radar. One thing is certain: Both aircraft were in a program code-named Oxcart. In January 1960, the Skunk Works got an order for 12.

Oxcart was to cruise at 90,000 feet and Mach 3.2—faster than a rifle bullet. At that speed, the friction of the air would create tremendous heat, but airframe heating in itself was not insurmountable. North American's X-15 almost routinely exceeded Mach 3 and in October 1967 would set a world record of Mach 6.7. But the X-15 flew supersonically for mere minutes, not for the many hours required of a long-range reconnaissance aircraft. The F-106, the nation's premier operational interceptor at the time and for years to come, could fly at Mach 2 for only 15 minutes at a time.

The heat that would be created by flying at Mach 3+ for long periods bedeviled engineers and required unparalleled inventiveness. As Kelly Johnson said, "Everything on the aircraft, from rivets and fluids, including materials and power-

Mounted atop a pylon on a range with instruments to measure an object's radar reflectivity, and equipped with long plugs to simulate its jet exhaust, this Lockheed A-12 full-scale mockup demonstrated that Mach 3 speed was not the aircraft's only advantage. One of the first stealthy airplanes, it employed shapes and coatings to minimize radar return.

LOCKHEED MARTIN

plants, had to be invented from scratch." Long before the A-12 flew, its designers calculated that their creation's leading edges would get hotter than a soldering iron, and without adequate cooling in the cockpit, it would literally get hot enough to bake a cake.

In early 1991, with the cold war over and much of the SR-71 declassified, the Graduate Aeronautical Laboratories at the California Institute of Technology presented a course entitled "Ae107, Case Studies in Engineering: The SR-71 Blackbird." The course was based on a detailed three-inch-thick engineering summary, and virtually every section of the book, whether the subject was grease, hydraulic fluid, engines, oil, electrical plugs, or tires, shared one word: heat.

To cope with both altitude and heat, a fuel called JP-7 was developed with an exceptionally high flash point: A lighted cigarette tossed into a pail of JP-7 would go out. This tolerance for high temperatures allowed it to be the airplane's primary heat sink. And there was a lot of it: The fuselage and inner wings formed fuel tanks with a capacity of 40 tons, and they were unlined, since no plastic liner could survive.

B.F. Goodrich came up with main landing gear tires that were compounded with aluminum powder to produce a silvery rubber that reflected heat from the airframe. And they were filled with nitrogen, not air, because oxygen would only incite combustion. The tires, which had a 22-ply rating, cost $2,300 apiece and were good for between 15 and 20 landings, depending on the pilot's touch. The wheel wells into which they retracted were shielded and surrounded by tanks of fuel that performed double duty as a massive cooling system. The heat sink worked by routing the fuel to a pump that raised its pressure to 45 pounds per square inch and sent it to several valves and heat exchangers, where it cooled subsystems before be-

LOCKHEED MARTIN (3)

SR-71 assembly line: dark wedge shapes mark the radar traps on the skin (right). Airplanes were crated before being shipped by truck (below), departing Burbank in the wee hours. Once in open country, they attracted little notice.

TED CARLSON

The blended body and its chines mirror boat hull design (top). Lockheed pilot Lou Schalk (center, facing camera) greeted company and government officials after the successful maiden flight of the A-12 on April 26, 1962.

ing returned to the tanks to be consumed in the engines. The JP-7 circulated throughout the fuselage and wings the way blood does in animals.

A hydraulic system was invented to operate between –65 and 650 degrees Fahrenheit. After responding to an ad in a technical journal touting a fluid that would work in temperatures as high as 900 degrees, Johnson received a large canvas bag filled with white powder. He called the manufacturer and was told that it would turn to liquid when it got hot enough. The problem was solved by Penn State's Petroleum Refining Laboratory, however, which came up with a super-refined petroleum-based oil that met the requirement.

The glass through which the all-important cameras peered had to be free of optical distortion even though the inside temperature was 150 degrees and the outside 550 degrees. (Pilots have reported that the windshield of an SR-71 gets so hot at cruise that they can't touch their gloved hand to it for more than a couple of seconds.) That one was solved by the Corning Glass Works and Perkin-Elmer, a lens manufacturer, in three years and at a cost of $2 million. They fused quartz glass windows to the metal frame using high-frequency sound waves, which had never been done before.

The A-12 was at first provided with three camera systems that were leaps in photographic technology. Perkin-Elmer developed a stereo camera that had an 18-inch lens and a 5,000-foot film supply. This Type I camera produced paired photographs of a 71-mile-wide swatch of ground with a resolution of one foot. Roderick M. Scott, Perkin-Elmer's resident genius, developed several innovations, including the use of a reflecting cube instead of a prism for the scanner and a concentric film supply and take-up system that minimized weight shift. Kodak created the Type II camera, also stereo, which covered a 60-mile-wide swath of territory with a 21-inch lens that resolved on the order of 17 inches. Hycon's entry, the Type IV, was designed by James Baker and was an advanced version of his B camera for the U-2. It took seven frames that, when combined, covered a swath 41 miles wide with a ground resolution of eight inches. The Type IV also held the most film yet: 12,000 feet. Later on, a Texas Instruments infrared camera that could take pictures day or night was adapted to the A-12 and used when the need arose.

Knowing that the difference between aerodynamics and hydrodynamics was basically a matter of density—that the air in front of their aircraft would not only get hot but, in effect, thicken as the speed increased—Johnson and his team designed the A-12 to cut through very hot, dense air the way a vessel cuts through water. (The idea dates back as far as Leonardo da Vinci, who wrote that both birds and fish "fly" through different fluids in the same basic way.) That's why the fuselage, a model of which was tested in a water-flow tank, was hull-shaped. And the forward part was stretched into what Johnson called a blended body. Its chines, when matched to a modified delta wing, dramatically increased lift

at cruise speed and reduced drag significantly because it allowed the whole aircraft to create lift. The chines also formed a series of bays that were stuffed with intelligence-collecting sensors and other equipment, including electronic countermeasures.

The speed of the A-12 came from a pair of 20-foot-long engines, each weighing 6,500 pounds, that were every bit as innovative and challenging as the aircraft they propelled. That corncob of an engine was refined over the years until it developed more than 32,000 pounds of thrust, or about a third of the thrust ratings of today's giant airline turbofans. Designed by Pratt & Whitney under tight security starting in late 1959 and designated the JT11D-20, it was developed for a Mach 3 Navy attack aircraft that was canceled by President Kennedy after the CIA convinced him that the need for a Mach-busting spyplane took precedence. It soon became better known by its military name: J-58-P2. Powerplant cognoscenti savor the J-58 as a true classic.

For security reasons, less than a dozen of the J-58's designers knew what the whole engine looked like or was supposed to do, recalls senior project engineer Joseph A. Daley Jr. Those who did were confounded at every stage by the heat problem, just as the airframe designers at Lockheed were. "The engine operates in the most hostile environment any engine has ever been subjected to," the Ae107 course book noted. "Air entering the compressor reaches 1,400° F. The turbine inlet temperature is 2,000° F. The temperature in the afterburner section reaches 3,200° F...."

Topped by the attitude indicator, the panel of the SR-71 in the National Air and Space Museum's collection is typical of what you'd find in any fighter of the early 1960s.

ERIC LONG/NASM

The inlet was a particularly tough problem. Early testing showed that high inlet temperatures would hurt the efficiency of the nine-stage compressor, which, to use engineering jargon, would run out of surge margin—the engine would stall. The problem was solved in a way that gives engineers existential pleasure and evokes the word "elegant." At the fourth compressor stage, air was bled off through six bypass tubes on the outside of the engine and routed back to the afterburner. This not only removed heat from the compressor, but caused the hot air blowing into the afterburner to arrive at the same speed as the air flowing into the inlet. The result of this was that at Mach 2, the inlet and afterburner were synchronized and therefore turned into a ramjet that provided about 80 percent of the J-58's thrust.

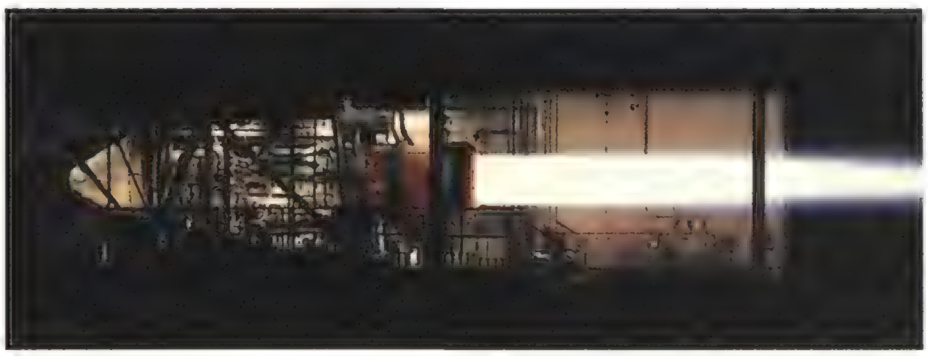
The J-58 weighed more than three tons, mainly because most of it was made with Waspaloy, a nickel-based alloy that even at 1,400 degrees keeps its strength and resists oxidation. But it is also very heavy and hard to weld. The first thin sheets of the metal used for fabrication experiments were supplied by the Hamilton Watch Company. Titanium was used for the front compressor blades because it is much lighter than steel and stronger than aluminum. The forging of the blades was an art form in a titanium industry that in the late 1950s was in its infancy. Not only were the blades meticulously hollowed on the inside for cooling, but the metal's grains were aligned for strength.

Pratt & Whitney executive Arnold J. Gunderson crystallizes the engineering challenge by pointing out that while the J-58 had parts that were machined to thousandths of an inch, the whole engine got so hot at cruise that it expanded two and a half inches in width and grew six inches in length. (The airframe expanded and contracted as well, which was why fuel leaked from its wings.) That problem was solved, says Gunderson, by putting the gear box that drives the generators, hydraulic pumps, and other subsystems on the bottom of the engine, where it effectively floats, and hanging the engine itself from the top of the nacelle so it could expand and contract without stressing its parts.

The heat also made the A-12 and the SR-71 trickier to land than to launch. Descending too quickly and shock-cooling the airframe and engines would cause a sudden shrinking of parts that could be more stressful than the expansion that occurred during heat-up. Pilots had to avoid cooling the engine at a rate that could cause shrinkage and make the ends of the turbine blades rub against their seals, ruining the engine.

Mach 3.2 was the A-12's (and then the SR-71's) design point.

LOCKHEED MARTIN (2)



With its skin removed, the airplane's cellular construction and wedge-shaped radar traps are clearly visible. Numerous bulkheads reduced fuel sloshing in the wing (above). Converting JP-7 to light and noise, a Pratt & Whitney J-58 at maximum thrust glows and howls on its test stand.

The airplane could hit Mach 3.6 and, in theory, Mach 4 if the air was cold enough. But, as Gunderson explains, "Kelly designed the airplane to fly at Mach 3.2 at 80,000 feet. The airplane cruises there. It is very, very comfortable there because that's the point at which it was designed to fly, where every system is snug and tight-fitting.... All of the enhancements and refinements we did over the many, many years of the program were done to reinforce that. Moving away created more problems than it was worth. Every time we flew faster and higher, we ran into areas where we had not so much experience. Things would go wrong. You'd swallow the [aero]spikes, you'd flame out."

Unlike their engines, 93 percent of the airplanes' structure and skin were made of titanium. The metal's quality varies widely, and the first batch of titanium sponge (which looks like a giant soap pad) had to be bought by the CIA from the Soviet Union and smuggled past U.S. Customs. Ironically, the Soviets had most of the world's supply of the metal and exported a product of exceptionally high quality. The plane's landing gear was the largest titanium forging produced in the United States and the only titanium landing gear in use in any U.S. aircraft. Forging and cutting special metals to tolerances as tight as .005 inch, then welding them together, were exotic specialties that were virtually developed from scratch.

Welding brought with it new mysteries. Skunk Works engineers were at a loss to explain why A-12 wing panels that were spot-welded in the summer failed early, while those that were welded in the winter held together indefinitely. They traced the trouble to a characteristic of titanium: It is absolutely incompatible with chlorine. "We finally traced the problem to the Burbank water system, which had heavily chlorinated water in the summer to prevent algae growth, but not in winter," Johnson related in a classified CIA journal article in 1982. "Changing to distilled water to wash the parts solved the problem."

The A-12's inlets, which include forward air bypass doors that automatically manipulate the air—and the famous spikes—were designed under Lockheed engineer (and later Skunk Works president) Ben Rich's supervision and are the key to the airplane's performance. The B-58 Hustler bomber used fixed spikes in front of its General Electric J-79s. Like his counterparts at Convair, Rich found that air hitting the unprotected front of a turbojet at high Mach numbers creates insurmountable pressure problems.

The spike's purpose was to control the supersonic shock wave and, by working in combination with doors and open-

Tough Customer

Going Mach 3 wasn't Johnson's only problem. Another was his customer, the Air Force itself. General Curtis E. LeMay, the stogie-chomping head of the Strategic Air Command, didn't like specialty items like the U-2, A-12, and SR-71. It was he who coined the term "boutique" for units that flew Lockheed's handmade spyplanes. LeMay believed in collecting intelligence, but he didn't want reconnaissance to come out of his budget, and he worried that such elite units would distract his workaday bomber crews. To LeMay, boutique aircraft were pricey, finicky, hard-to-maintain, limited-edition peacocks flown by "prima donnas" (as he put it). What he wanted, first and foremost, was the Air Force's bread and butter: bombers and ballistic missiles that could go to war, not "odd-balls" (as he also put it).

LeMay spoke for himself. But while the Air Force readily bought and used SR-71s, his words haunted the 9th Strategic Reconnaissance Wing at Beale Air Force Base in California, which operated them. Blackbird crews tended to feel like they were in an orphanage. Colonel Richard H. Graham, an SR-71 pilot, wrote, "The SR-71 never had a legitimate place in SAC—our entire program was always considered their step-child." Justin Murphy, the Skunk Works SR-71 most recent program manager, couldn't agree more. "Sure, we were a wonderful thing to have for airshows," the former SR-71 pilot says. "We didn't fly with nukes, we weren't a bomber, we were kind of just out there."

ings to bleed away excess air, prevent supersonic airflow from entering the compressor intake. It accomplished this trick by moving back 26 inches into the throat of the inlet on a programmed schedule as the speed built up in a manner somewhat like the way the nozzle on a garden hose changes to adjust the water's flow. At Mach 3.2, each inlet swallowed about 100,000 cubic feet of air a second.

When a spike failed to work perfectly, which happened repeatedly for many years, supersonic air pressure instantly built up and choked the compressors. They reacted without warning by violently spitting the shock wave back out. This event was the dreaded "unstart," which, at Mach 2 or higher, would cause a thunderous bang that the crew heard and felt, while the airplane jerked so violently in the direction of the unstarted inlet that, according to Lockheed Martin's Garfield Thomas, "it was like running into a brick wall." He remembers one unstart yaw violent enough that the pilot "slammed his head so hard against the sill on the window [that it] cracked the helmet and knocked him semi-conscious." A computer restarted the inlet, Thomas adds, and the pilot survived.

Blair L. Bozek, a reconnaissance systems officer with extensive experience with SR-71s, says an unstart at Mach 3.2 "is like driving on the highway fast, taking an off ramp, hitting black ice, and having your car slam into the guard rail." Justin Murphy, SR-71 program manager at the Skunk Works, remembers that "the way you knew which side the unstart was on was which side of your head hurt." Bud Wheelon observed that Lockheed test pilots were "remarkable in their ability to delay normal human emotional reactions to chaos. In Area 51 [the flight test area at Groom Lake, Nevada], I've talked to them on the radio. They were calm as can be and very clinical, until they came down. And then they'd start weeping."

The problem in the early days, says Wheelon, was that the hydraulic servo that moved the spike reacted too slowly to changes in Mach number. He told Johnson that hydraulic fluid can only move so fast; it has friction and inertia, and he began to advocate that the spikes be moved electrically.

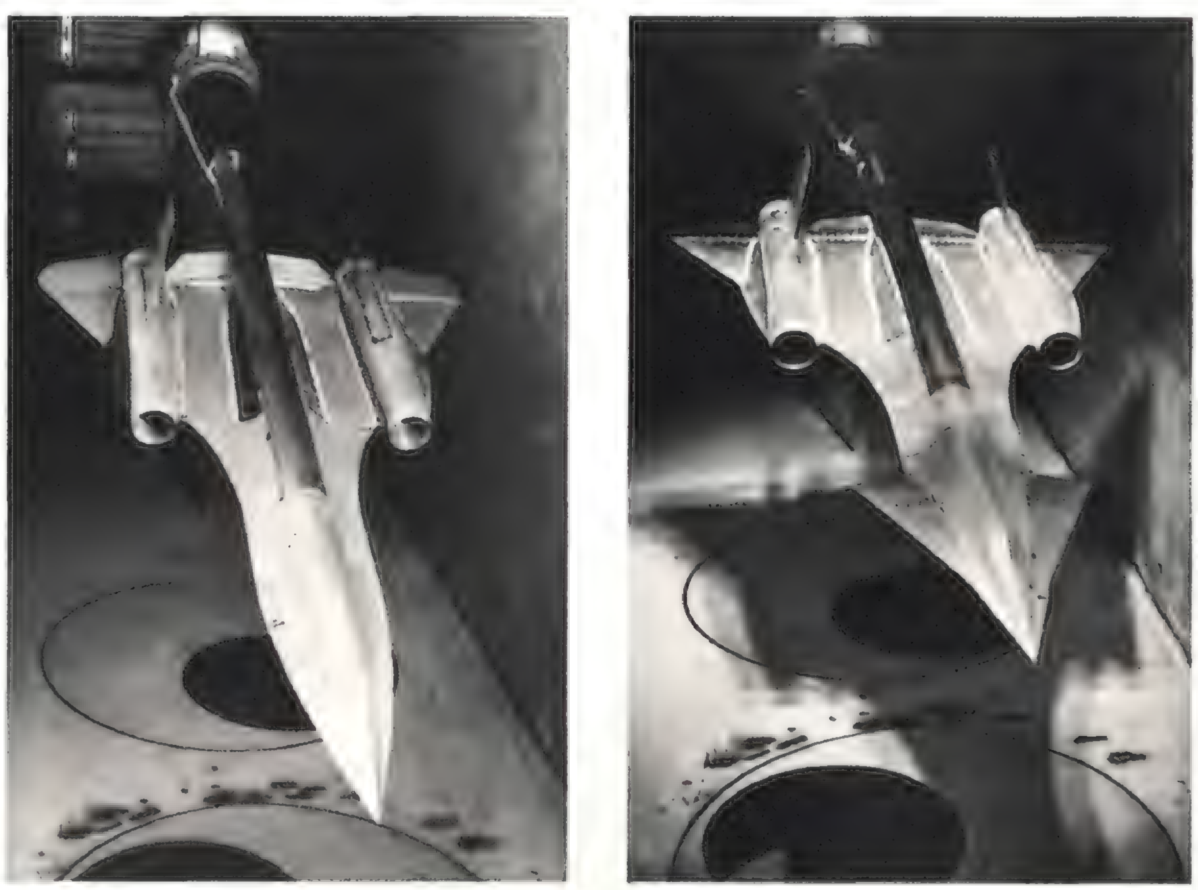
"What you have to know about Kelly Johnson is that he's everything everybody says he is," Wheelon explains, still using the present tense more than six years after Johnson's death at the age of 80. "He's a wonderful guy. But he's a stubborn son of a bitch to boot. And Kelly did not trust electronics." Johnson also knew that electronic systems did not fare well in an engine that got as hot as the J-58 did.

"We've got $30 million invested in this servo," Wheelon quotes Johnson as saying, "and we can't just run a truck over it."

"Every time we crack up an airplane we spend that much money. And we're killing people," Wheelon says. Of the initial group of 18 F- and A-12s, seven had been lost with at least two fatalities, though not all instances were attributable to the servo. Losses of SR-71s continued during the mid-1960s.

But Johnson was absolutely adamant: "I'm not going to have electronics in the airplane."

The final outline of the A-12 (left) did not include canards or forward lifting surfaces like those on an early wind tunnel model (right). Tunnel data matched flight test data closely except for higher drag in transonic flight.



LOCKHEED MARTIN (3)

A-12s line up for a family portrait at Nellis Air Force Base in Nevada, where housing, hangars, a fuel tank farm and a runway extension were constructed between 1960 and 1964.

"Kelly," Wheelon recalls responding, "you're the world's greatest aeronautical engineer. But this program is going to stop unless you put an electronic servo on that thing. Now take your pick."

Wheelon says that Johnson went to Washington, apparently to go to someone in the agency over Wheelon's head. When he came back he told Wheelon that he had decided to go to the electric servo. But that may have been sheer guile, because hydraulic actuators are still used in the few SR-71s still flying. The number of unstarts was greatly reduced when the system's analog computers were replaced in 1983 by far faster and more sensitive digital ones as a result of the development of a Digital Automatic Flight and Inlet Control System. The DAFICS computer, working closely with the spikes and other inlet components, reverses unstarts in fractions of a second.

Pratt & Whitney's Arnold Gunderson has thought a lot about his supremely powerful but high-strung engine. The J-58 is complex, and each of its systems is coupled in some obscure way with other systems, which meant that all these relationships had to be learned.

"Every time you make an improvement, you've ruined or degraded something else," Gunderson observes. "If you optimize something here, you've made it significantly less optimal somewhere else. Now, you've got an engine, which is a highly complex thing, with its own internal subsystems. You've got a completely self-contained afterburner control system, a self-contained main engine control system. You've got the spike going back and forth along its 26-inch path. You've got the four bypass doors that regulate the static pressure inside the duct. When they're closed, it's maximum ram recovery. When they're open, you create drag. All of these things affect the entire propulsion system. Now, that's just the main features.... Every time we made a minor change in how the engine worked," he adds, "it had to go back into an integrated engineering approach with the entire propulsion system."

The problems plaguing the engine in the beginning caused delays of months and would have financially broken the program had the Navy not bailed it out with $38 million. Every serious problem that afflicted the J-58 was given a number, and the list eventually reached more than 270. "ENC—Exhaust Nozzle Control instability—was problem number 6," Gunderson says. "It was still an active problem in 1974. Even then we were trying to figure ways to keep the engine stable. As you can imagine, it goes back a long, long way."

Some J-58s, like a couple of the airplanes they powered, absolutely refused to work properly no matter what was done to them. Gunderson says that any J-58 whose parts were fundamentally unhappy with one another for no apparent reason was disassembled and their parts saved to repair other engines.

The SR-71s also had marked differences. Thomas maintains that each Blackbird had a distinct personality and that careful records documented them as clearly as diary entries. "I could tell you something different about each one of those airplanes," he says. Number 974, which perished in the South China Sea near Luzon after a catastrophic engine failure, gave its crews all it had. Justin Murphy agrees, and says the same about 971. Author and former SR-71 pilot Richard Graham swears that 962 "never let us down." But 959 was a hangar queen, an absolute "lemon," according to Thomas. "You could never get everything to work at the same time. The Air Force said, 'Come and get it. We don't want it.' " There were also problems with the defensive system, but they were philosophical, not technical. Johnson believed so strongly that his supersonic spyplanes would be adequately protected above 80,000 feet at Mach 3.2 that he vigorously resisted equipping them with electronic countermeasures.

Wheelon recalls that he tangled with the always weight-conscious Johnson over ECM too. Wheelon won, and as a result, the A-12 and SR-71 were equipped with the newest defensive systems.

And the opposition never gave up the notion of trying to bag one, as it had Francis Gary Powers' U-2. He can't recall the precise designation but Gunderson remembers a Soviet missile that had the theoretical capability of flying up in front of an SR-71, then plunging down and hitting it at Mach 6—a nearly impossible feat because there was almost no warning that the airplane was coming. Still, there was always the possibility that one would get hit by a "golden BB."

It was certainly in the back of the Air Force's collective mind. The airmen were concerned that if the airplane went down carrying ECM hardware all of the fighters and bombers that carried the same equipment would be compromised. Yet not installing it could have hastened the day when one of the high fliers was shot down.

While the U-2 was given a very simple ECM system, says Thomas, the SR-71's electronic bays were crammed. All of the ECM equipment, plus the SR-71's nose-mounted high-resolution optical bar camera and its side-looking radar and other sensors, were operated by the reconnaissance systems officer, or RSO, who sat behind the pilot. The CIA's A-12 had one pilot who ran everything, but the Air Force decided that the load was too great, so it had the Skunk Works make room for the RSO.

That change and others created real differences in both airplanes' performances. The A-12 actually flew up to 5,000 feet higher than the SR-71, was a bit faster, and had cameras that could cover three times as much territory with better resolution. The penalty for adding a crewman was a smaller camera. "The A-12 was like the U-2," says Bob Murphy, the SR-71 plant manager. "It had a massive camera, a very, very large camera, whereas in the SR-71, the second guy sits where the massive [Type I] camera went in the A-12."

Whatever its limitations relative to the A-12's camera, the SR-71's was by all accounts good enough. According to Ben Rich, it could peer more than 130 miles into a targeted territory. It is still used on U-2s and remains classified. The SR-71's performance was also somewhat reduced by the side-looking radar it carried, plus gear that collected electronic and communication intelligence by sniffing out radars and listening to radio transmissions.

The CIA's contract for the A-12 specified that it have very-low-observable qualities but not that it be completely stealthy. Still, the low-observable specification was a problem that had to be solved before the contract was finally signed in February 1960. Its blended body reduced its radar reflectivity dramatically. Its overall shape, including the two vertical tails that cant inward plus lots of curves, helped to hide it. So did special radar-absorbing plastic panels made of silicone and asbestos that had to be formulated to withstand temperatures of roughly 550 degrees.

What was more difficult, according to Thomas, was shaping the surfaces so that they intercepted, captured, and absorbed or redirected radar signals (see "The Invisible Men," Apr./May 1997). The trick was to guide the radar signal around the aircraft before either dissipating it or redirecting it. He describes the plastic panels as a series of gradually phased "steps" that accomplished this with exquisite nuance. "An enormous amount of invention had to go into this thing," Thomas says, "and it was all done simultaneously in a matter of 31 months." And, as almost everyone who was involved likes to point out, nearly all the engineering was done with slide rules and calculators rather than computers.

Besides creative genius, Kelly Johnson had an aggressive and practical business sense. When he thought up the A-12, he saw the airframe as the equivalent of a basic automobile chassis that could be assembled as a sedan, a convertible, or a station wagon. The key was to use different forward fuselages on the same basic body, wing, and tail. The separation point was at Frame 715, which connected the wings at the roots of their leading edges. Everything behind 715, including the nacelles and their inlets and engines, remained essentially the same while the forward fuselages differed. The basic design was therefore turned into a long-range missile-

All Blackbirds depend on aerial refueling and routinely take off only partly fueled to reduce weight. With refueling, one aircraft made a flight of more than 15,000 miles.

toting interceptor called the YF-12. Another version, the M-12, carried a ramjet-powered, camera-carrying drone called the D-21 on its back. "M" stood for mother; "D" for daughter. The thing was used briefly over China with mixed results and one of the D-21s destroyed the M-12 that carried it when it slammed into the aircraft during separation.

There were even plans that never materialized for a penetrator version that could have carried nuclear missiles. Pratt & Whitney's Joseph Daley says that the Soviets at the Strategic Arms Limitation Talks in the late 1960s insisted that it not be built because "if it was used offensively, there was no way in the world you could defend against it."

And there was yet another permutation—a bizarre one. SR-71 lore has it that the airplane was really designated RS, for Reconnaissance Strike, but that President Johnson mistakenly called it the SR when he announced it in 1964; the name stuck and it became Strategic Reconnaissance.

In fact, the SR-71's stated mission when it was created was not to collect routine intelligence but to do "post-strike reconnaissance" a few days after World War III began. With air bases and much of the United States reduced to radioactive rubble, the Pentagon's war planners would have wanted to locate Soviet targets that were still standing, according to Daley, as part of the ultra-secret Single Integrated Operating Plan by which the war was supposed to have been fought.

The Strangelovian plan called for moving two SR-71s and a C-141 transport full of support equipment and photo-interpreters to remote bases like Mozambique or Diego Garcia. With the first missile and bomber exchanges over, the SR-71s would scour the U.S.S.R. for remaining targets and get the information to the Navy's missile submarines so they could continue the ballistic beating. The pilots would have been provided with eye patches, Daley adds, "so when the things [submarine-launched missiles] go off, you still have one eye that can see." With what remained of the 15 A-12s mothballed, and with World War III averted, the 31 expensive SR-71's were put on regular reconnaissance duty until they were finally retired in January 1990, only to be revived in on-again, off-again directives from Congress.

And to show that the aircraft was infinitely flexible, there was a version that could go to orbit, at least in the imagination of a whimsical engineer at the Skunk Works. Included in the Caltech Ae107 course book was an image of an SR-71 bolted to a shuttle external tank containing JP-7 and two solid rocket boosters. No air-breather can reach space, of course, but it certainly captured the spirit of the enterprise.

LOCKHEED MARTIN

1020
HIGH
1028
HIGH
1024
NATIONAL WEATHER SERVICE

How's the Weather Up There?

Twice daily the world over, 950 balloons answer that question.

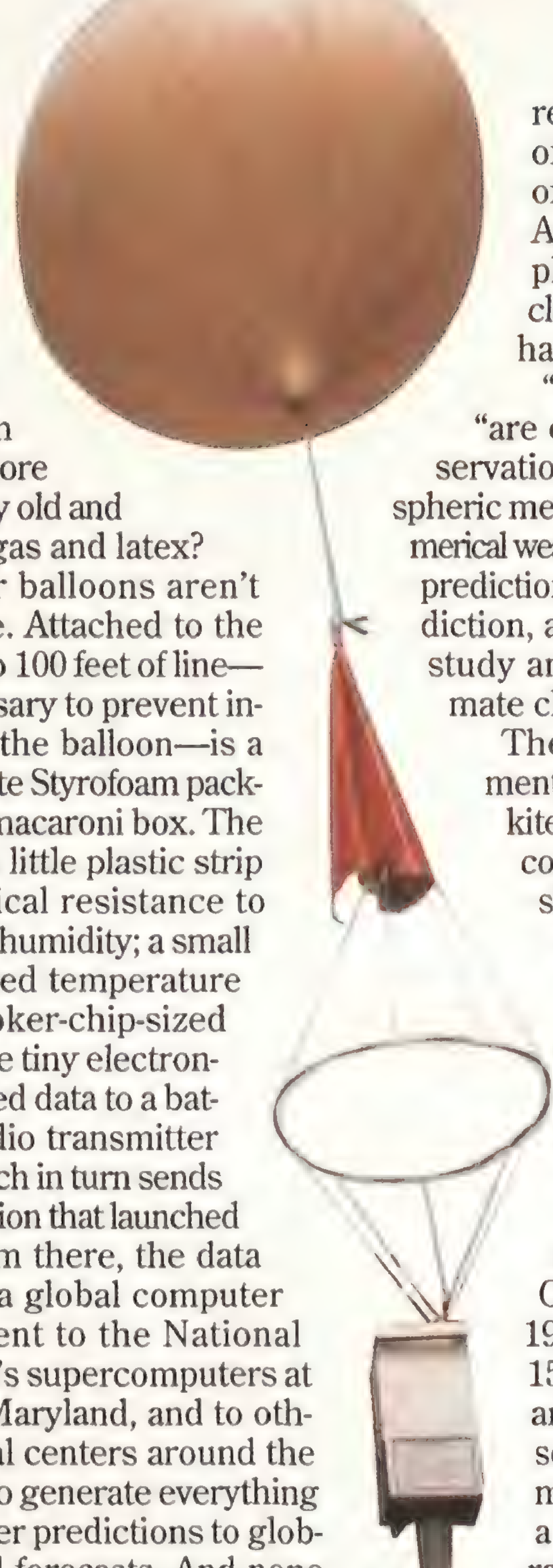
by Phil Scott

Illustrations by David Peters

He calls it "working the upper air." At precisely four o'clock this morning Mountain Standard Time—that's 1100 Hours Universal Time, formerly Greenwich Mean Time—meteorologist Dennis Clark will cross his fingers and attempt to wrestle a bobbing yellow-green hydrogen-filled balloon roughly his height from a storage shed at Riverton, Wyoming. Then, as he has done some 3,750 times over the past 23 years, Clark will give the whole shebang a gentle toss skyward—unless, of course, the wind is blowing. In that case the balloon will try to drag Clark up with it. ("That's why I always cross my fingers," he says.)

Simultaneously, from about 950 locations around the world—places like McMurdo Station, Antarctica; Antsiranana, Madagascar; and the Kamchatka Peninsula of Russia; as well as on 15 specially equipped ships at sea—weather people will launch similar balloons skyward. They, or their shift replacements, will do it again in exactly 12 hours. And yet again 12 hours after that.

In an era when geosynchronous satellites monitor continent-sized weather fronts and half-billion-dollar Doppler radar systems scan the atmosphere for storm activity—and both silently feed reams of data to massive supercom-



puters that generate complex models of weather patterns—why is it that the most vital component of the world's weather forecasting system is a technology more than half a century old and made mostly of gas and latex?

Well, weather balloons aren't quite *that* simple. Attached to the balloon with 75 to 100 feet of line—a distance necessary to prevent interference from the balloon—is a radiosonde, a white Styrofoam package the size of a macaroni box. The sonde contains a little plastic strip that uses electrical resistance to measure relative humidity; a small glass-encapsulated temperature sensor, and a poker-chip-sized barometer. These tiny electronic instruments feed data to a battery-powered radio transmitter on the sonde, which in turn sends the data to the station that launched the balloon. From there, the data is encoded into a global computer language and sent to the National Weather Service's supercomputers at Camp Springs, Maryland, and to other meteorological centers around the world. It is used to generate everything from local weather predictions to global environmental forecasts. And none of these would be possible without two critical types of measurements gathered exclusively by weather balloons: the temperature of the air and its water content at various altitudes.

Without this information, airline pilots wouldn't know when and where icing conditions exist. Thunderstorms and flash floods would roll in unannounced. If you want to determine the possibility of snow, explains Carl Bower, who manages Upper Air Program operations for the U.S. government's National Weather Service, "you have to have some indication of the moisture and temperature aloft that could lead to large snowfall. Are temperatures cold enough and is there sufficient moisture in the area that would provide two inches of snow or 16 inches?"

Weather satellites can provide some relevant data, but they don't offer clear, precise readings of temperature and humidity. And with satellites, Bower explains, "once you get below clouds, you don't know what's happening.

"Weather balloons," he adds, "are one of the most critical observation tools for obtaining atmospheric measurements required for numerical weather prediction, severe-weather prediction, air pollution transport prediction, aviation operations, and the study and prediction of global climate change."

These simple-looking instruments are the descendants of the kites Benjamin Franklin and his contemporaries lofted into the sky carrying a thermometer or barometer. Meteorologists continued to rely on kites up until World War II, but the technology had its drawbacks. Kites needed plenty of open space in which to be launched, as well as huge reels of piano wire for tethers. At one Oklahoma weather station in 1921, three kites on a single 15,400-foot wire broke loose, and for 52 hours station personnel tracked them across muddy roads, river beds, and a forest four inches deep with rainwater to wrestle the last kite down.

An escapee kite trailing a huge length of out-of-control piano wire presented all sorts of problems besides lost data. The tether could sever communications lines, for example (one runaway tether cut all the telegraph lines between Dallas and Houston), and, as electrification spread across the country, loose tethers also posed fire hazards. Then, too, they were vulnerable to being severed themselves by the increasing number of aircraft filling the sky. In the mid-1930s, the last weather kite was reeled in for good.

During the late 1920s and 1930s the U.S. Weather Bureau (later to become the National Weather Service) began using balloons but mostly without instruments, just to get a rough idea of how the winds were blowing. One advantage: Balloons could be launched without wind. In fact, that's how they work best. But, like kites, weather balloons back then were tethered, since in those pre-radio days the data would be recorded on a clockwork-driven drum and then the balloon would be dragged back to earth.

And balloons were far more expensive than kites. To take specific readings, the Weather Bureau used airplanes, eventually taking temperature, humidity, and air pressure readings each morning from some 30 stations across the United States. For the pilots of these planes, the work was brutal: They had to ascend to 17,000 feet in all kinds of weather in aircraft that lacked oxygen equipment.

By the outbreak of World War II, the development of synthetic latex and refined manufacturing techniques made producing weather balloons cheaper and easier. Likewise, radio equipment had become small and light enough to launch beneath a balloon, and it and the instrument package almost inexpensive enough to lose without regret. And with war breaking out around the world, thousands of men training and traveling in aircraft staked their lives on the knowledge of the upper air's temperature and humidity. Weather balloons became a part of the war effort.

Irene Brodie, then of Wichita, Kansas, recalls that at the time, the Weather Bureau faced a shortage of men to staff its stations. "The official in charge at the Wichita Weather Bureau put out a notice that they had vacancies in 13 western states, and any women already in the Civil Service interested in becoming a meteorological aide should apply," she says. Brodie and a handful of other women went to Kansas City for six weeks of training, including a course in handling the brand-new RAOBs ("RAY-obs")—radiosonde observation balloons. Completing the course, Brodie was given her choice of locations. She picked Lander, Wyoming, in part because as a flat-lander, she wanted to see mountains.

For the young woman from Wichita, every day brought a new and interesting experience. There was equipment to master: To visually track the balloon's altitude and drift, she and her co-workers used a theodolite—a ground-based

surveyor's instrument with a telescope and a numerical scale for measuring vertical angles; a recorder with a pen and a roll of graph paper that spat out the weather data transmitted from the radiosonde; and a teletype, which sent the data along to Denver, where it was incorporated into weather maps. In the winter Brodie would warm herself on an old water heater while inflating balloons. For fun, she and the others would take the occasional breath of helium so they could talk in that weird voice.

Brodie left the bureau in 1947 when she married a rancher. A few years ago she paid a visit to the new station, at Riverton, where she got a tour from the personnel there, like Dennis Clark (who in addition to launching the balloons, oversees the recording of weather data and does some forecasting). "Everything there is all computers," she says, "but there in the corner was the old recorder that I had used. I was tickled to see it."

Today, the recording of the balloon data is automated. In many ways, though, sending weather balloons aloft hasn't progressed much in the half-century that has passed since Irene Brodie left the weather business.

The typical weather balloon is three feet long when flaccid, and grows to a diameter of six to seven feet when inflated with helium or the less expensive but highly explosive hydrogen. On calm days launches tend to be uneventful; in windy conditions, things can get a bit hairy. "One time we had a 35- to 40-knot wind and a guy headed out the door to let the balloon go and he disappeared," says Clark. "I found him about 10 minutes later picking cactus needles out of his leg. The balloon had dragged him into a cactus bush before he could let go."

For tracking purposes, the balloon and its package are designed to ascend at a rate of approximately 1,000 feet per minute. The station's radar tracks the balloon's radio signal and uses trigonometry to calculate wind speed and direction. It may drift perhaps 125 miles from the station (or as far as 250 miles if swept up in the jet stream). The balloon is engineered to reach as high as 100,000 feet (19 miles). In such a thin atmosphere it will expand to the size of a two-car garage. (People who spot them floating around when the light is right tend to believe that they've seen something extraterrestrial. "It happens a lot in Florida, where they launch at dawn and sunset," says Clark. "If the sun hits it right, it can look pretty interesting in the evening sky.")

The National Weather Service launches more than 72,000 weather balloons a year. All that stuff floating about in the atmosphere sounds hazardous to aerial navigation, yet the computer files of the Aircraft Owners and Pilots Association's Air Safety Foundation, which go back to the early 1980s, reveal no instance of a collision between an aircraft and a weather balloon. In any such encounter the weather instrument would come off the big loser: Federal law requires that the 8.8-ounce radiosonde be designed to disintegrate harmlessly if it strikes an aircraft.

Once a balloon reaches the altitude prescribed by its design, the inevitable occurs: It bursts. As it tumbles earthward, an orange paper parachute (made

by Unicor, a business operated by prisoners at the Leavenworth federal penitentiary) deploys, slowing the radiosonde for a gentle landing somewhere below. And that's when the journey can take a strange turn.

For radiosondes can and will land anywhere. Most simply float down into the wild and are never heard from again. But that's not always the case. "I was standing outside at the weather station," recalls Dennis Clark, "and this pickup drove up. The guy had something in his hand, a mangled bunch of string and Styrofoam that resembled a radiosonde. 'Where'd you get that?' I asked him. 'It landed in the trees near my house,' he says. 'I thought it was something the Russkies sent over. So I took my .22 and shot the hell out of it.' "

What the man discovered, once he'd blasted the commie device into submission, was a set of instructions that tell what the radiosonde is, where it comes from, and what you should do if you stumble across one. That is, put your gun down, place the sonde inside the canvas shipping bag that comes free with every sonde, and take it to the local post office, which will send it off to the proper authorities at no charge to the finder.

Regardless of where an American-launched radiosonde drops, once it's in the hands of the U.S. Postal Service it is forwarded to the weather service's National Reconditioning Center in Kansas City, Missouri (which, despite the name, merely inspects the sonde before sending it on to the manufacturer for the actual reconditioning). Of the 185 radiosonde-launching nations in the World Meteorological Organization, the United States is the only one that recycles its sondes. Out of 6,000 launched each month, an average of 1,500 arrive at the Kansas City center. The rate picks up in the fall, when the leaves drop and hunters stumble across them.

For some, finding a sonde is an exciting event. "Occasionally we'll get a call from a radio station, or a copy of a newspaper article where a police officer is holding a radiosonde under the headline 'WEATHER INSTRUMENT RECOVERED,' " says Alan Morris, head of the reconditioning center. "Sometimes it's the biggest news that's happened in a small town in a year or two."

Some people look upon a radiosonde as opportunity descending from the heavens. "A very small minority come back where the person is trying to claim something from damage," Morris says. "Someone once said one had broken her picture window, but they're very lightweight and really the amount of damage they can do is limited. Imagine a block of Styrofoam the size of a shoebox falling on your head—you wouldn't notice it. Or sometimes one gets eaten by a farmer's cow, and it's always his *prize* cow."

Sondes can on occasion inflict real damage: They've been known to land in power lines and blow out transformers. In any case, all claims for damages caused by errant sondes are sent on to Washington for adjudication.

If a sonde does get returned, it can be reconditioned for an average of $20 (new, they're $50 apiece). One hardy specimen returned six or seven times, but generally, Morris says, you can't guarantee reliability past two uses, so reconditioned sondes are sent to island sites, where they'll fall into the water and be lost forever.

What about the weather balloon's survival as a species? The technology's main drawback is the manner in which it measures wind speed and direction. It takes a balloon an hour or more to rise to altitude, and in that time the wind can fluctuate rapidly. Then, too, once the balloon begins to drift it's not really measuring the winds vertically over one place but somewhere downwind. Though for special events like a shuttle launch, NASA's Kennedy Space Center in Florida will send up an additional 10 balloons (shuttle launches have been scrubbed because of unfavorable winds), for everyday measurements at an average airport, "it's not practical to launch a lot of balloons and get a lot of winds," explains Frank Merceret, chief of the Kennedy center's applied meteorology unit.

One solution: a ground-based instrument known as a Doppler Radar Wind Profiler. Essentially a big box ("It looks like a big set of bed springs," says an NWS spokesperson), a Profiler bounces a radar signal off moisture in the air; by measuring the change in the signal when it comes back, meteorologists can learn wind speed and direction with about the same accuracy as a balloon—and they can take a new reading in as little as five minutes.

Still, balloons won't be grounded any time soon. "I'm in favor of using Wind Profilers, but not of getting rid of weather balloons," says Merceret. While a Profiler can measure a mixture of humidity and temperature known as virtual temperature, it can't yet measure temperature and humidity separately. But, he adds, the old-fashioned radiosonde can.

"There's a fair amount of discussion on when radiosondes will be replaced," says the weather service's Carl Bower. "There's an interest in decreasing the weather balloon network and integrating other platforms."

One candidate: jetliners. The World Meteorological Organization has begun experimenting with a reporting system in which airplane-borne sensors take soundings at various altitudes and report back using the onboard communication and avionics systems. The National Weather Service is experimenting with something similar in UPS airplanes and other aircraft. The big drawback, though, is that such a system can report only up to the airliner's cruising altitude, which is usually below 40,000 feet. A weather balloon can reach 100,000 feet.

Science will one day devise a replacement for weather balloons, but you won't be finding them next to the manual typewriter and the horse-drawn buggy in technology's Jurassic Park anytime soon.

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>SIGHTINGS<

The stated aims of the first flight over the world's highest peak—the Houston Mount Everest Expedition of April 1933—were to demonstrate the ideal match of aircraft and camera for mapmaking and to study conditions for flying in mountain ranges. But the underlying reason for the flight was similar to that given by climber George Leigh Mallory: "Because it is there."

The Westland Aircraft Corporation loaned a British expedition team, led by Colonel L.V.S. Blacker, two open-cockpit biplanes equipped with supercharged 525-horsepower Westland Pegasus engines (above). Upper winds were calculated to be 60 mph, and updrafts and downdrafts tossed the aircraft 2,000 feet in seconds. Both the photo and observer aircraft ended up clearing the 29,000-foot peak by 500 feet. "Immediately over the summit we came into the [ice] plume, and so violent was it—being composed of large particles of ice, that the windows of the cockpit were broken," wrote Blacker, a passenger in the observer aircraft. After 15 racking minutes over the summit, the Westlands returned to land a little the worse for wear, but the crew had glass plate negatives in hand. Mission accomplished.

TURBO POWER

The Development of Jet and Turbine Aero Engines (second edition) *by Bill Gunston. Haynes Publishing, 1997. 239 pp., b&w photos, graphs, outline and cutaway drawings, glossary, and index, $39.95 (hardcover).*

When the tachometer hit 2,000 revolutions per minute, he opened the main fuel valve. "With a rising shriek like an air-raid siren, the speed began to rise rapidly, and large patches of red heat became visible on the combustion-chamber casing," Frank Whittle recalled. "The engine was obviously out of control." But at 8,000 rpm, the revs slowly began to drop. The engine survived. It was April 12, 1937, and Whittle had just completed the initial test of the world's first turbojet engine.

It's all here: the people and the principles, the quirks of history, and the complexities of gas turbine combustion-chamber thermal flow. The history spans from the prototype Whittle Unit to the 100,000-pound-thrust GE-90 turbofan on versions of Boeing's new 777, not to mention the massive 16,250-horsepower Zaporozhye D-27 propfan on the Ukraine's new An-70 transport prototype.

The author of *World Encyclopedia of Aero Engines* and more than 100 other books, British aviation writer Bill Gunston stands at the peak of his profession. Now, in *The Development of Jet and Turbine Aero Engines*, he outlines the principles of jet propulsion, showing how turbojet, turbofan, and turboprop engines power helicopters, commercial aircraft, military bombers, and fighters. Moving from intake to tailpipe, he describes in detail what happens inside each section of a jet engine. He also covers engine placement, sound suppression, and thrust reversal.

Notable in the book's second half is the story of how Whittle overcame professional jealousies and bureaucratic inertia that blocked his development of the jet engine. Then, in 1939, Hans von Ohain's turbojet took off in Germany's Heinkel He-178. "If the British experts had had the vision to back Whittle, World War II would probably never have happened," observed von Ohain. "Hitler would have doubted the Luftwaffe's ability to win."

And we read that years later, when the failure of its RB.211 bankrupted Rolls-Royce, the legendary Stanley Hooker was called from retirement. He chose a different alloy for the high-pressure turbine blades and selected different nozzle guide vanes (stator blades) for the turbines. In only one week, he saved the entire program.

But in Gunston's analysis of today's more efficient compressor blades, there's no mention of Richard Whitcomb, the brilliant NASA aerodynamicist whose area rule and supercritical airfoil designs revolutionized transonic airflow management in fighter aircraft fuselages, jetliner wing profiles, and controlled-diffusion compressor blade airfoils.

Gunston points to turbine-powered jetliners and air freighters that over the last 30 years have tripled payload, doubled range, made possible a 30-fold improvement in safety, and cut noise generation by 98 percent. As turbine power plant operating temperatures and performance rose, aluminum and steel gave way first to nickel and titanium alloys, then to the metal matrix and ceramic matrix composites used today. Single-piece compressor blisks (blades and disk machined from one solid alloy casting) are replacing disks with multiple blade inserts, and the engine parts count is dropping, simplifying maintenance and cutting manufacturing costs.

In addition, Gunston offers

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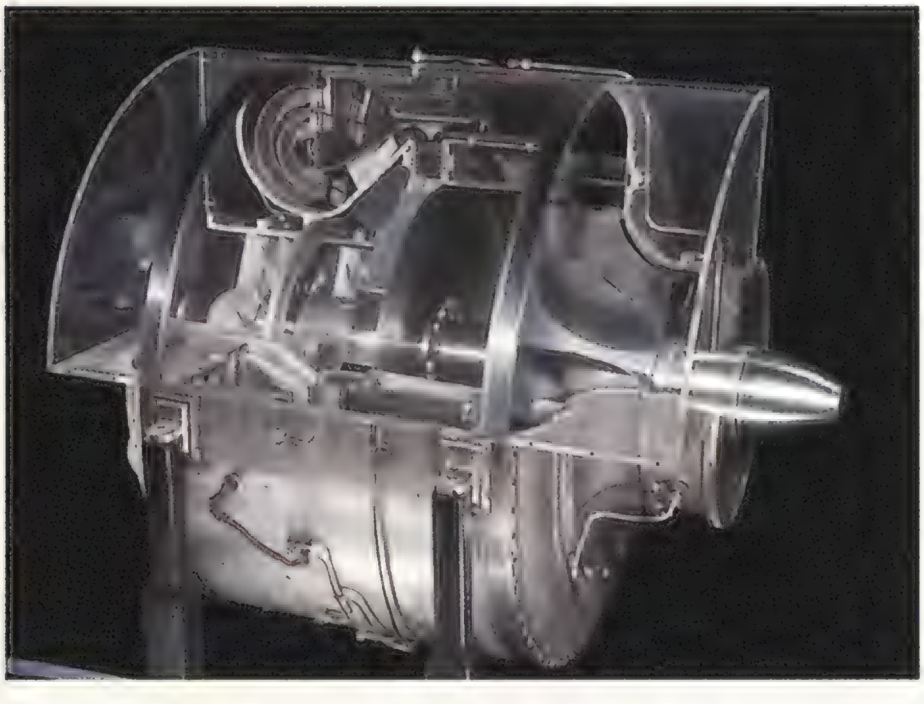
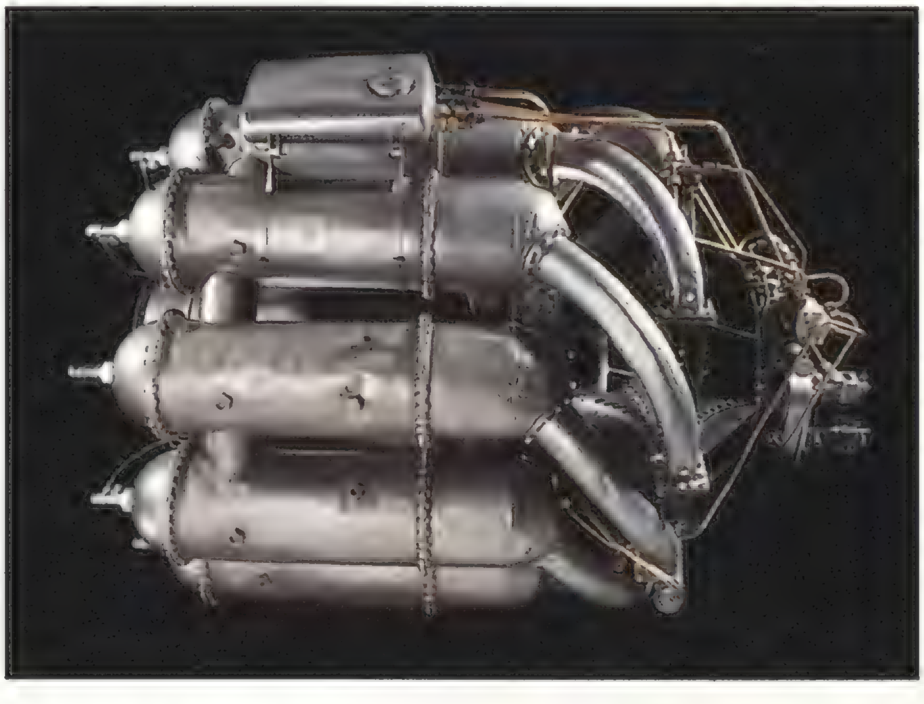




Hans von Ohain's HeS3B and Frank Whittle's W1X turbojet engines put a whole new spin on aeronautical propulsion.

considerable information not normally accessible, such as photographs and schematic diagrams of Pratt & Whitney's immense nuclear-powered ducted fan and the giant General Electric X-211 (J-87) turbojet proposed for the WS-125A nuclear-powered bomber. He also describes the use of "active clearance control"—spraying cooling air around the outside of compressor and turbine casings to shrink-wrap them more closely around whirling compressor and turbine blade tips, thus cutting air-gap pressure losses to absolute minimums.

In the final section, "Jet and Turbine Update," Gunston shows how the debut of Boeing's 777 sparked airline turbofan thrust increases from 60,000 pounds to more than 100,000 pounds between 1994 and 1997. He explains complex nozzle flap technology entering production on two engine types being evaluated in Lockheed Martin's F-22 Raptor, plus much more.

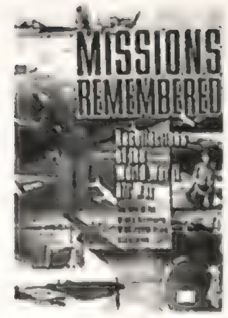
Gunston's slips are minor. In describing ingenious horizontal/vertical-thrust technologies being developed for competing prototypes of the Joint Strike Fighter, "the largest combat-aircraft development effort in the world," he doesn't mention that Russia reportedly shared its Yak-141 supersonic V/STOL (vertical/short-takeoff-and-landing) fighter's rotating-nozzle engine technology with Pratt & Whitney. And in discussing applications of the JT8D turbofan, he says that "in every case it was mounted outside the airframe"—forgetting Boeing's 727 tri-jet, whose center engine resides in the rear fuselage beneath the vertical stabilizer.

For decades, Smith and Sheffield's 1955 edition of *Gas Turbines and Jet Propulsion* stood as a classic. Nevertheless, Bill Gunston's comprehensive *The Development of Jet and Turbine Aero Engines* eclipses this predecessor, presenting with lucid explanation and anecdotal detail the origins, workings, and growth of a complex modern technology.

—Theodore L. Gaillard Jr. is a Philadelphia-based writer specializing in technology and military issues.

Missions Remembered: Recollections of the World War II Air War by the Men of the Middle Tennessee WWII Fighter Pilots Association. *McGraw-Hill, 1998. 320 pp., $22.95 (hardcover).*

In 1992, a handful of fighter pilots living in the Nashville area got together to reminisce about their service in World



War II. At first seeking only "nostalgia, fellowship, and fun," the 33 members of the group eventually decided to corral their bull sessions into a book. The result, *Missions Remembered*, is an odd but engaging gallimaufry of the men's wartime exploits.

Never mind the passage of 55 years—most of these vignettes have the immediacy of after-action battle reports. For Captain Johnnie Corbitt, crashing a Republic P-47 into the crown of a Lombardy poplar on a 1944 strafing run over Belgium was an "experience…just as vivid today as it was then." Lieutenant Eugene Pargh, who flew a Grumman Wildcat from carriers in the Pacific and North Atlantic, remembers "the boys I served with and the things we did better than I recall what I did or whom I met last week."

In a book filled with men jawing about their prowess as aerial warriors, it's a relief to learn that in flight training, they were royal screw-ups. Navy Lieutenant Frank Davis, applying "shrewd calculations regarding wind and flight direction," got lost and had to land his Stearman biplane in a muddy cattle pasture 40 miles from his intended target,

the Naval Air Station at Olathe, Kansas. Johnnie Corbitt—of later Belgian tree-trimming fame—dropped his navigation map on his first cross-country flight but hit upon a brilliant way to retrieve it: "When I inverted the plane, all the dirt and trash on the floor fell into my face, along with the map." And Captain Charles Mott spiced up a routine patrol of the West Coast by flying his Lockheed P-38 under the Golden Gate Bridge. "I returned to base feeling like a real ace," says Mott. "What I didn't know was my antics had been reported.... [M]y feelings regarding my superior flying techniques vanished under the verbal assault I received."

The assaults turned lethal soon enough, as the men shipped out overseas and got their first taste of combat. For P-47 pilot William Miller, the reality of war was jolting. "A hit by machine-gun bullets," he discovered while dive-bombing a Japanese airfield in Hankow, China, "feels and sounds like small scattered sleet and hail pellets striking an automobile."

Shortly, though, the fliers began dishing out such punishment themselves. They learned that the Achilles heel of a Messerschmitt 109 was its left wing root, which housed the fuel pump; that a P-51 could turn inside a Focke-Wulf 190; and that, despite their Stateside training in deflection gunnery, "the surefire way to be successful was to shoot from directly behind the enemy."

These hard-earned lessons brought victory in dogfights—and vivid passages half a century on: "[Porky Anderson] caught a 109 low on the water and moved in close," recalls Captain Lee Gossick of a battle over the island of Pantelleria, "his tracers lacing out in red threads to walk a stitched pattern up the side of the Messerschmitt. A short puff of dirty black smoke gasped from the belly of the 109 followed by a tongue of flame. Then there was a burst of bright orange, and the Gustav [a Bf 109G] came apart in the air."

Not every mission remembered here was an aerial duel, however. As U.S. forces gained air superiority in China and Western Europe, enemy ground troops became increasingly vulnerable to slaughter from the sky.

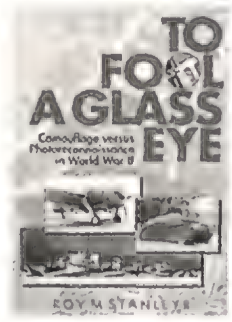
Some of the pilots recognized—and pitied—the infantry's plight. Major George Blackburn caught six barges crammed with German soldiers crossing the Po River in northern Italy on a February day in 1945. Because the barges were also carrying 88-mm guns, Blackburn "had no choice" but to barrel in and shoot them up. "As I raked across the barges," he recalls, "...I was appalled at the carnage those .50 calibers could inflict on a human being."

Other fliers, however, come off in these pages as callous in the extreme. Miller, describing himself in one episode as "especially bloodthirsty today and...looking for Japanese to kill," characterizes strafing the unarmed occupants of a Japanese troop train as a "turkey shoot." His hatred was kindled by the brutality of the times; Miller was seeking to avenge the death of his best friend, U.S. pilot Roggy Rogenbauer, whom the Japanese had dragged through the city of Hankow by a rope tied around his neck. Still, Miller's stereotyping is offensive: The Chinese are "inscrutable," the Japanese "crafty."

Tougher editing would have shot down such gaffes. It might also have kept this collection from feeling quite so fragmented; the book is broken into 85 episodes that average four pages long. At re-creating the adrenaline rush of early aerial combat, however, *Missions Remembered* drops the reader squarely into the flier's seat—and the pilot's mind: "The 3 years and 4 months I spent in the Navy will always be with me," notes Lieutenant Pargh. "Those who were not with us would never understand.... It was the greatest 40 months of my life, but I would not want to do it again."

—Allan Fallow, director of new-product development at Time-Life Education, was a writer and editor for Time-Life's Epic of Flight *and* World War II *series.*

To Fool a Glass Eye: Camouflage versus Photoreconnaissance in World War II *by Roy M. Stanley. Smithsonian Institution Press, 1998. 192 pp., $37.95 (hardcover).*



Roy M. Stanley, a retired Air Force colonel with decades of experience in military intelligence, has written a careful, enjoyable, and heavily illustrated book that documents how camouflage has been used in order to protect objects from aerial observation.

Stanley states in his introduction that modern photo-reconnaissance systems make camouflage virtually useless. Given the right camera, a good photograph, and a well-trained photo-interpreter (PI), it is impossible to hide man-made objects from above because, Stanley notes, "there are no straight lines in nature." But his focus in this book is World War II, and he explains that while camouflage even then could often be ineffective against trained

PIs, it might easily fool the aviator zipping along at 300 mph and 15,000 feet.

Stanley divides the subject into seven chapters. The first is an introduction to camouflage and photo-intelligence. Others deal with camouflaging land targets, naval targets, aircraft and airfields, railways and canals (roads were too obvious and too unimportant), and industrial targets. The last chapter provides three case studies in successful large-area camouflage.

Stanley stresses that camouflage is a dynamic field, often as much art as science. Successful camouflage is never successful for very long. Eventually the PI looking at photos for hours at a time notices things that give the target away. Certain planes that never move are probably decoys. Cut foliage dies and fades, revealing objects concealed underneath.

It is the photographs that make this book fascinating. They are used to illustrate every point, demonstrating why a particular camouflage effort was successful or unsuccessful, and what might have worked better. Many are not only previously unpublished but were actually captured from German and Japanese sources. There are German reconnaissance photos of Russian attempts to conceal the Kremlin, and a captured Japanese photo of the interior of Douglas Aircraft's massive Santa Monica production factory. The photos often demonstrate the ingenuity of those on the ground: The Rocklea munitions plant in Brisbane, Australia, was covered with wire mesh and a false road that went over the roof. The Germans occasionally built entire dummy factories to lure away Allied bombs and often heaped debris on top of intact buildings to make them look as if they had already been bombed.

But even good camouflage is undone by sloppiness. A line of well-concealed Japanese barges along a jungle tree line was exposed because several other barges moored along a nearby beach looked blatantly artificial and drew attention to their sisters. A pair of Japanese aircraft carriers, moored along an artificial island and heavily draped with camouflage netting, would have gone unnoticed if other carriers had not been moored in the same bay, thus causing the PI to examine the whole area carefully.

Even when camouflage is successful, it does not always equate to a strategic advantage. Toward the end of the war, the Japanese navy had perfected the art of camouflaging its ships in port. The reason? They almost never left the dock. Meanwhile, the U.S. Navy controlled the Pacific.

—Dwayne A. Day is a writer on military, space, and reconnaissance issues.

"UNIDENTIFIED FLYING OBJECT" OFFICIAL CONTEST RULES

1) NO PURCHASE NECESSARY

2) To enter hand print on a 3 1/2" x 5 1/2" postcard your name, address and telephone number, date of the issue cover, correctly identify the "unidentified flying object" illustrated, and be sure to follow instructions on the feature page. No mechanically reproduced entries permitted. You may enter as many times as you wish, but each entry must be mailed separately.

3) Each entry must be postmarked no later than the last day of the month on the issue cover and received by the 10th of the month following the issue date. Mail entries to: Air & Space/Smithsonian Magazine Contest, 901 D Street SW, 10th Floor, Washington DC 20024.

4) Six contests: (1) December 1998-January 1999, (2) February-March, (3) April-May, (4) June-July, (5) August-September, (6) October-November 1999 issues.

5) One winner will be randomly selected from all correctly answered entries from each of the six contests by Marden-Kane, Inc. an independent judging organization whose decision in all matters relating to the rules and administration of the contest is final and binding. Each of the six contests' winners will be awarded a Garmin 111 Handheld Satellite Navigator, approximate retail value $350.00 each.

6) SECOND CHANCE GRAND PRIZE DRAWING. In addition to the prize awards for the six contests, a "second chance" random Grand Prize drawing will take place on December 10, 1999. All eligible entries from all six contests will be automatically entered in the Grand Prize drawing. The prize...a $2,000 voucher for flight training provided by G. A. Team partner flight training facility. Winner will be provided with a list of facility locations. Transportation to and from the facility not included. Total A.R.V. of prizes $4,100.00.

7) Winners will be notified by mail. All entries become the property of Air & Space and none will be acknowledged or returned. Contest open to legal residents of the U.S. and Canada 18 years of age or older at time of entry. Void in Quebec and Puerto Rico and wherever prohibited. Employees of Smithsonian Institution, advertising and promotional agencies, contributors to Air & Space and their families not eligible. Canadian winners will be required to answer an arithmetical skill question administered by mail.

8) Odds of winning each contest dependent on the number of correct entries. Taxes, if any, are the sole responsibility of the prize winner. All Federal, State, local and provincial laws apply.

9) Sponsor not responsible for damage, losses or injury resulting from the use and acceptance of a prize. Winners consent to use of name and/or likeness for editorials, advertising and promotion purposes without further compensation, except where prohibited by law. No substitution or transfer of prize permitted.

10) For a complete winner's list, available after December 10, 1999, send a stamped, self-addressed envelope to Air & Space "Unidentified Flying Object" Contest Winners, 901 D Street SW, 10th Floor, Washington DC 20024

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CREDITS

Signatures From Earth. Charley Kohlhase is a planetary mission designer, author, artist, and teacher. During his JPL career, he led efforts to design missions to all of the planets except Mercury and Pluto.

Old 'Hog, New Tricks. William L. Smallwood is the author of *Warthog: Flying the A-10 in the Gulf War* (Brasseys, 1995).

High Society. John Fleischman is a features editor at *Yankee* magazine.

Talk Radio. Greg Freiherr is an *Air & Space/Smithsonian* contributing editor and the author of "Space Beat," a bimonthly department for the *Air & Space* Web site (www.airspacemag.com).

On Your Mark, Get Set, BLOW! Joseph Bourque is a private pilot who lives in Montana.

Bring Me the Tail of Wild-2. Michael Milstein's last article for *Air & Space* was "Surfing the Solar System" (Dec. 1997/Jan. 1998).

The Oxcart Cometh. William E. Burrows is the author of *This New Ocean: The Story of the First Space Age* (Random House, 1998). He teaches journalism at New York University.

Further reading: *Sled Driver: Flying the World's Fastest Jet*, Brian Shul, Mach 1, 1992.

SR-71 Blackbird, James Goodall, Squadron/Signal, 1995.

Lockheed Skunk Works, Steve Pace, Motorbooks, 1992.

Lockheed SR-71, Jay Miller, Aerofax, 1995.

How's the Weather Up There? Frequent contributor Phil Scott is a New York City-based freelance writer. He wrote "What I Learned at Kitplane Camp," which recounted his experience at the Experimental Aircraft Association's airplane building academy in Oshkosh, Wisconsin (Oct./Nov. 1998).

Bad News for the Boll Weevil. Frequent contributor Richard Sassaman travels the United States when not working out of his home in Bar Harbor, Maine.

CALENDAR

February 6 & March 6
EAA Chapter 690 Fly-In Pancake Breakfasts. Briscoe Field, Lawrenceville, GA, (770) 613-9501.

February 21–23
Helicopter Association International's HELI-EXPO. Dallas, TX, (703) 683-4646.

February 21 & March 21
Open Cockpit Sundays. Sit in helicopters, fighters, and a DC-3. New England Air Museum, Bradley International Airport, Windsor Locks, CT, (860) 623-3305.

March 7 & April 4
Nike Missile Site Open House. Fort Barry, Sausalito, CA, (415) 331-1453.

March 13 & 14
Rocky Mountain Air Fair. Wings Over the Rockies Air & Space Museum, Denver, CO, (303) 659-7265.

March 18–20
International Women in Aviation Conference. Radisson Twin Towers Hotel, Orlando, FL, (937) 839-4647.

March 19–21
Cox Communications Air Show Spectacular. Warbirds and modern military aircraft. Williams Gateway Airport, Mesa, AZ, (602) 774-9355.

April 7–10
Gathering of Mustangs and Legends. This year's event is expected to draw approximately 80 P-51s and many more pilots from across North America. A training seminar on flight safety and aircraft maintenance will be offered for P-51 owners and operators. Kissimmee, FL, (407) 846-4051.

Organizations wishing to have events published in Calendar should submit them four months in advance to Calendar, Air & Space/Smithsonian, *901 D St. SW, 10th Floor, Washington DC 20024; fax: (202) 287-3163. Events will be listed as space allows.*

ON THE WEB SITE

From Lockheed's lecture series at the California Institute of Technology, an explanation —with diagrams—of how the SR-71's famous engine spikes work. Only at www.airspacemag.com/ASM/mag/supp/FM99/oxcart.html

LOCKHEED MARTIN

'HOG HEAVEN

CHAD SLATTERY

The latest *Air & Space/Smithsonian* Web site video shows you the A-10 in action. See it now at www.airspacemag.com/ASM/mag/supp/FM99/hog.html.

FORECAST

In the Wings...

SHOW TIME!

An *Air & Space/Smithsonian* special to ring in the airshow season.

•Before the Thunder
The teams who flew P-51 Mustangs, F-84 Thunderstreaks, and F-86 Sabres before the world-famous USAF Thunderbirds came to town.

•The Voice
The fine (and funny) art of airshow narration.

•FREE POSTER!
If you don't make it to a show this summer, you'll definitely want this collector's item gathering the planes, performers, and panache of the 1999 season.

The Ghosts of Aviation Past
On a leisurely tour in his Piper Super Cub, photographer Russ Munson finds a few definitely-not-roadside markers of aviation history.

The Cape
It was little more than a mangrove swamp occupied by snakes, 'gators, and a few humans. Then some guys showed up with modified V-2 rockets, and a place called Cape Canaveral started making the news.

Guiding Light
How did the U.S. military get laser-guided weapons accurate enough to drop down the air vent of a command center? It all started back at the Than Hoa bridge...

VIETNAM MEMOIR

JOHN HEINLY

Bad News for the Boll Weevil

The National Agricultural Aviation Museum is a little different from most aerospace collections: The first thing you see upon entering is an enormous rocking chair. It has nothing to do with agricultural aviation; the rocker is there because it was made by one of Mississippi's renowned craftsmen, Greg Harkins, and this aviation museum is part of a larger complex devoted to the state's rural heritage and achievements.

The Mississippi Agriculture and Forestry Museum—41 buildings on 39 acres—includes a restored cotton gin, sawmill, rose garden, schoolhouse, blacksmith shop, Masonic hall, and print shop. The aviation area, inside the Heritage Building, documents the history of cropdusting.

It was in the South that the practice of cropdusting really took root, especially in the delta areas of Louisiana and Mississippi, where the boll weevil had crossed north from Mexico around the turn of the century and was plaguing the region's cotton crop. By 1909 southwest Mississippi was infested. To investigate methods of insect control, the U.S. Department of Agriculture set up the Delta Laboratory in Tallulah, Louisiana, an organization that by the late 1920s had turned into a private cropdusting company called the Delta Air Service. (The operation continued to expand, and today is known as Delta Airlines.)

The agricultural aviation museum includes a sampling of the most popular cropdusters used in the years since then. There's a Boeing-Stearman Model A75 biplane that once worked as a duster-sprayer in Texas. Lloyd Stearman's two-seater design made its name as a superb trainer during World War II, when over 8,000 were built (see "Back to the Basics," Oct./Nov. 1994). The Stearman quickly became the workhorse of ag aviation after the war ended, when thousands became available at surplus prices, ranging from $250 to $900. Converted for use with hoppers and spreaders, many are still flying today.

A mid-1950s Grumman Ag-Cat is on loan from the Texas Department of Agriculture. The Ag-Cat was one of the first airplanes designed specifically for cropdusting, with spreaders built into the wings, an air-powered pump to move chemicals to the spreaders, beefier landing gear than the Stearman's, and an enhanced ability to recover quickly from stalls. An industry favorite, the Ag-Cat has been in continuous production for over 40 years. Two Pipers complete the collection, a 1963 A Model Pawnee from the Texas panhandle and a J3 Cub built in 1946 and converted in 1957 to a cropduster.

The National Agricultural Aviation Museum, 1150 Lakeland Drive (exit 98-B on I-55), Jackson, MS 39216. Phone (800) 844-TOUR. Open Mon.–Sat., 9 a.m.–5 p.m., plus Sun., 1–5 p.m., between Memorial Day and Labor Day. Closed New Year's Day, Thanksgiving, Christmas Eve, and Christmas. Admission 50¢ to $4, depending on age.

Surrounding the airplanes are scale models of other cropdusters, samples of hardware used for spraying liquids and spreading powders, other aircraft parts, and dozens of historic photos. One wall displays photographs of the 30 or so men (and so far there are only men) enshrined in the National Agricultural Aviation Hall of Fame. There's Kenneth "Kinky" Shane, the first pilot to plant rice by air in Texas; Hugh Wheelless Sr. of Dothan, Alabama, the first to convert B-17 bombers for combat against fire ants; and Mabry Anderson of Clarksdale, Mississippi, whose book, *Low & Slow*, chronicles the history of cropdusting. (In it, one observer of an early mission recounts: "Then the D-H [de Havilland] wobbled away to the end of the field, headed into the wind, and took off over the trees. She was bad news for the boll weevil!")

The oldest member of the Hall of Fame is Army Lieutenant John Macready, the pilot credited with flying the first cropdusting mission (and who later made the first nonstop flight across the United States). On August 31, 1921, Macready took off from McCook Field near Dayton, Ohio, flew 10 miles north, and, in an easy 54-second pass, dropped his Curtiss JN-6H low over a grove of catalpa trees. From the Jenny's rear seat, Etienne Darmoy, using a crude metal hopper he'd invented, let loose a load of powdered lead arsenate to exterminate an infestation of sphinx moths.

Margie Fitzgerald, the longtime curator of the agricultural museum, recently stepped down from her position, but she still visits occasionally and is always happy to discuss her favorite artifacts, the airplanes. On a recent visit, "Miss Margie" and I sat and rocked in two of the many normal-size Greg Harkins chairs scattered among the exhibits.

"Ever meet a cropduster?" she asked. "You've got to meet one, personally. They're very adventurous, with lots of camaraderie. They're like a fraternity—not reckless, but they give the appearance of being reckless."

Gesturing toward the Stearman, Miss Margie said, "Most of the old ones, they're flying this plane here. Some say this was the best plane there's ever been."

"You mean aerodynamically?"

"That's what they say. I don't know anything about it."

"You know more than most people."

"Well, that's because I've fooled with it."

The former curator regretted not being able to display an early Delta Air Huff-Daland cropduster—"They wouldn't give it to me; the company has their own museum up in Atlanta"—and she lamented the disappearance of an early agricultural Bell helicopter that once hung inside—"It was on loan to us from a man, there was a divorce, and she got it."

But overall, Miss Margie said, her years with the National Agricultural Aviation Museum were very happy ones. "The men associated with this are such fun," she explained. "Those old pilots, they're all deaf as a post, they can't hear a thing. But they're fun."

—*Richard Sassaman*